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Characterizing Land Use Change Trends Around the Perimeter of Military Installations

Robert C. Lozar, William D. Meyer, Joel D. Schlagel, Robert H. Melton, Bruce A. MacAllister, Joseph S. Rank, Daniel P. MacDonald, Paul T. Cedfeldt, Pat M. Kirby, and William D. Goran

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Characterizing Land Use Change Trends Around the Perimeter of Military Installations

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Final Report

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Arlington, VA 22209

Under Work Unit CNN-Q134#

ABSTRACT: The Total Army Basing Study (TABS) office, as one aspect of their stationing study, wished to determine the rate of development near the boundaries of nearly 100 military installations throughout the United States. The Engineer Research and Development Center proposed that this could be done by comparing the urbanization as derived from Ikonos images (taken around 2003 and acquired for all Services through the National Geospatial-Intelligence Agency) to a digital land use data set developed by the United States Geological Survey in about 1992. This decade difference could then be used to determine not only the amount of development, but also the trend. For the military, increasing development near installation boundaries can limit the ability to carry out their primary responsibilities of military training readiness and material testing activities. A team of 10 professionals was able to carry out the analysis for all the installations in about 4 months. This document describes the standard procedure used and the generalized results for the trends in increased development near the installation boundaries. It also summaries the urbanization trends from the statistics generated to provide a snapshot of encroachment characteristics near a sample of nearly 100 military installations.

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Conversion Factors

Non-SI* units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

** Système International d'Unités* ("International System of Measurement"), commonly known as the "metric system."

Preface

This study was conducted for the Deputy Assistant Secretary of the Army, ATTN: Colonel William Tarantino, Office of DASA(IA), 1400 Key Boulevard, Nash Building, Suite 200, Arlington, VA, 22209, under MIPR project number MIPR4CTABG4026, “To Characterize Land Use Encroachment Trends Around the Perimeter of Military Installations.” The project was initially conceived and coordinated by William D. Goran, Engineer Research and Development Center/Construction Engineering Research Laboratory (ERDC/CERL).

The work was performed by the Ecological Processes Branch (CN-N) of the Installations Division (CN) at CERL and the Remote Sensing/GIS Center of the Cold Regions Research and Experiment Laboratory (CRREL). The CERL Principal Investigator was Robert C. Lozar. The technical editor was Gloria J. Wienke, Information Technology Laboratory. Stephen Hodapp is Chief, CN-N, and Dr. John Bandy is Chief, CN. William D. Goran is the associated Technical Director. The Director of CERL is Dr. Alan W. Moore.

Both CERL and CRREL are elements of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

Land use changes in the immediate vicinity of military installations can result in constraints being imposed on mission and resource management operations on these installations. The Department of Defense (DoD) labels these changes that result in constraints as “encroachment.” Encroachment can compromise sustained and future training and testing missions at an installation.

Recent advances in computer analysis techniques based on remotely sensed satellite images can be used with other geographic information systems (GIS) data to establish a baseline of land use change near military installations. New land uses, especially new urban and suburban uses, may in some way conflict with the ongoing activities at an installation. Military installations are increasingly asked to alter activities within their boundaries to alleviate land use conflicts. Examples include restrictions on aircraft flights and firing ranges.

The concept of following the trend of urbanization within a region and predicting how it might continue into the future has been developing for several decades (Steinitz 1967). The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL) has engaged in several research projects investigating the assessment of risk to installation missions from increased development near installations (Deal 2001; Deal et al. 2002; Fournier et al. 2002; Lozar 2003a, b; Lozar et al. 2003; Timlin et al. 2002; Jenicek et al., 2004).

As a basis for studies that purport to predict the future, it is a good idea to have a clear sense of what has happened in the past. One approach developed at ERDC/CERL is an installation-specific historical urban growth series (Timlin et al. 2002). Several studies have advanced this historic approach to improve graphic presentation of changes over time and replicability of the approach from site to site (Lozar 2003a, b; Lozar et al. 2003).

Meanwhile, the DoD has implemented an effort, through the National Imagery and Mapping Agency (NIMA) [this organization is now called the National Geospatial-Intelligence Agency (NGA)], to acquire high-resolution (1- and 4-meter) commercial satellite imagery (Ikonos, composed of 1-meter Panchromatic integrated with 3 bands of 4-meter true color) for many major DoD installations. This data normally

includes a 1-mile buffer and often more than a 5-mile buffer around the installation perimeter, plus additional data within the image-bounding box.

The Ikonos data provides a consistent visual data source, for installations in all the services. Although the Ikonos imagery will be consistent, current, and have sufficient resolution for good visual inspection, this data by itself will not provide a good indication of "trends" in land use change.

There is a national data source, collected and analyzed by the U.S. Geological Survey (USGS) from LANDSAT TM (Thematic Mapper) images acquired in the early 1990s. The resulting National Land Cover Data (NLCD) can be compared to the Ikonos imagery to identify the "difference" in land use patterns around the perimeter of installations over the course of the past decade. For purposes of encroachment issues at installations, three "urban" categories used by the USGS are the most relevant to the issues discussed here. These categories are: 21 = Low Intensity Residential; 22 = High Intensity Residential; and 23 = Commercial/Industrial/Transportation.

To evaluate the degree of residential and urban growth near installation boundaries, a procedure or protocol was needed to use the available data sources (NLCD data and Ikonos imagery) in an objective manner that could be applied to military installations. This protocol needed to be clear, easily explained, and easily repeated by several different analysts.

Objectives

The objectives of this research project are to:

- Establish the urban growth trends in areas surrounding a military installation.
- Provide intelligently based projections of future growth and change.

Approach

The approach to achieve these objectives is to:

1. Develop a Protocol for using the Ikonos images for an objective, comparable evaluation of land use change along the edges of military installations.
2. Apply the Protocol to selected military installations to evaluate the relative degree of near-boundary land use change. Analyses were completed for each installation using 1- and 5-mile buffers (if the available Ikonos imagery allowed analysis for the complete 5 miles). Land use changes were determined by comparing

the NLCD (http://landcover.usgs.gov/natllandcover.html) to the land use categories derived from the Ikonos imagery.

3. Evaluate the statistics generated from the land use change study to characterize both the state of "urbanization" encroachment near military installations and the character of the statistics themselves.
4. Project the rate of change out to the year 2020.

Scope

This study deals only with land use changes, with specific emphasis on urbanization trends. After completing a historical trend analysis, the next logical step is to provide projections of future change.

The intent of this study was to obtain results that are highly consistent internally due to the application of a single standardized approach, referred to in this document as the Protocol. Because of the time restriction and the need for internal consistency, the research team selected a simple and straightforward method.

Actual restrictions at a given installation will depend on the type of training and testing activities present and their spatial location in relation to the land use change taking place beyond the installation boundaries. It was beyond the scope of this work to determine or compare the training and testing activities present at specific installations and the extent of current or potential future mission impacts.

Due to the nature of the Total Army Basing Study (TABS), the list of installations evaluated will not be made available in this document. Further, any graphics used will be of the most general nature. The identity of any installation will be obscured and example data presented for a specific installation will be modified so that it cannot be recognized.

It is acknowledged that the installations selected for this study do not represent a random sample. The TABS Office (sponsor of this research) supplied the list of installations. On the other hand, this is the only large sample of military installations in existence to have undergone such a detailed and comparable evaluation.

Mode of Technology Transfer

This report will be provided only to the office of the Deputy Assistant Secretary of the Army, DASA-IA, Arlington, VA.

2 The Protocol

The research team developed a Protocol using initial installations that were intended to represent the different sizes, environments, and mission types. The team compared the situation at two time horizons: 1992 when the NLCD were generated, and about 2003 when many of the Ikonos images were taken. Two buffers corresponding to the Ikonos imagery coverage outside the installation were to be targeted and evaluated:

- 0 to 1 mile and
- 1 to 5 miles.

The Ikonos imagery has some drawbacks for this tasking, including multiple resampling and inseparable integration of data in the imagery, multiple dates of acquisition, and nonavailability of some data. However, the data was adequate for the intended purpose; the comparative nature of how TABS uses the results is not significantly impacted as a result of these limitations. Other imagery sources (Landsat, ASTER, SPOT) could be used, but the Ikonos imagery was selected for the Installation Visualization Tool (IVT) data, which is the source data for this analysis. Any other source imagery would not have been available in a consistent manner for so many sites.

Rarely, the buffer extent had to be limited by the extent of the Ikonos images available. Using commercial spatial software packages (mostly ESRI's[*] ArcGIS and ERDAS Imagine), the research team developed a Protocol using the Ikonos imagery to characterize the more recent land uses within the buffer. Since the imagery had only three spectral bands, an unsupervised classification provided the input for the initial characterization. Additional procedures were developed to further refine and interpret this raw data. Thus, the Protocol resulted not only in an indication of the current land uses, but also data about the land use changes near installations that have the potential to restrict or impact the military training and testing activities occurring within the installation. The intent was to apply this simple Protocol quickly to many locations. The basic products were:

[*] ArcGIS is a product of ESRI GIS & Mapping Software, 380 New York Street, Redlands, CA 92372-8100. ERDAS Imagine is a product of Leica Geosystems GIS & Mapping, LLC, 2801 Buford Highway, N.E., Atlanta, GA 30329-2137. This does not constitute endorsement by the Army Corps of Engineers or the Department of Defense.

- Protocol Procedure for identifying Land Uses and Land Use Changes within the immediate vicinity of installation boundaries.
- Maps and tables showing the trends within the buffer. One item will be the change in the land near installations (e.g., Table 1).

Table 1. Final product of historic and projected growth.

Legend	Total Urban %	% Increase per year	Trend to 2020 % Urban
1992 0- to 1-mile buffer	1.9		
2003 0- to 1-mile buffer	15.9	1.6	45
1992 1- to 5-mile buffer	1.4		
2002 1- to 5-mile buffer	18.0	1.9	53

Conceptually the Protocol was divided in seven major steps (Figure 1). These allowed sensibility related tasks to be completed. These seven were further divided into a series of substeps. Both levels of organization allowed project tracking as well as the ability to intelligently provide hand-off points among team members with responsibilities for the accomplishing different tasks.

These steps are visually presented as they actually might look at a fictitious installation in Figure 2.

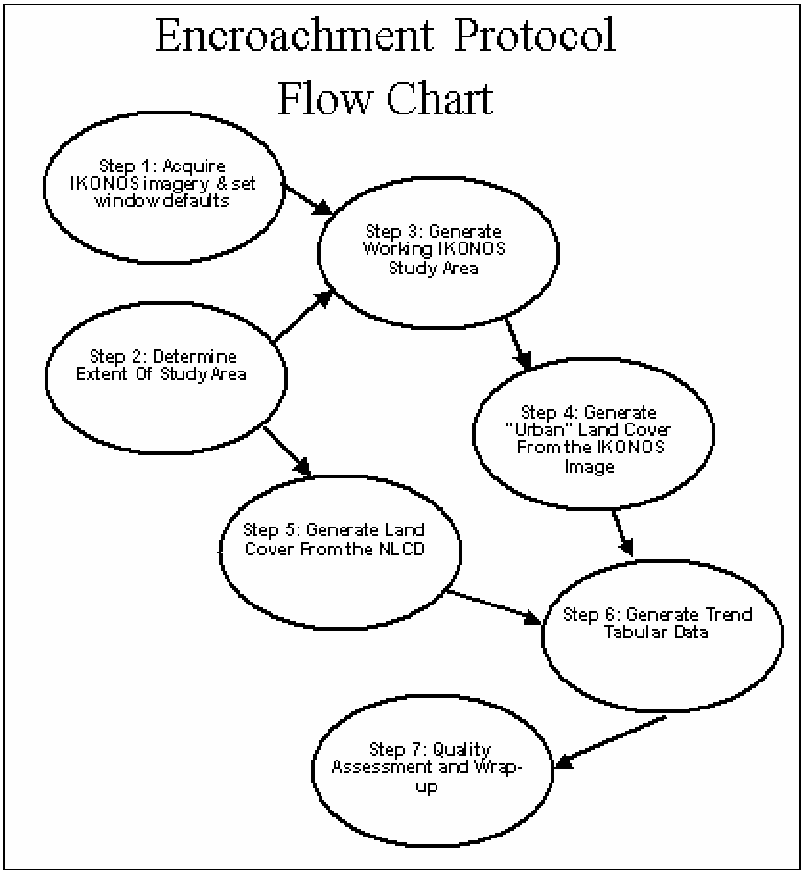
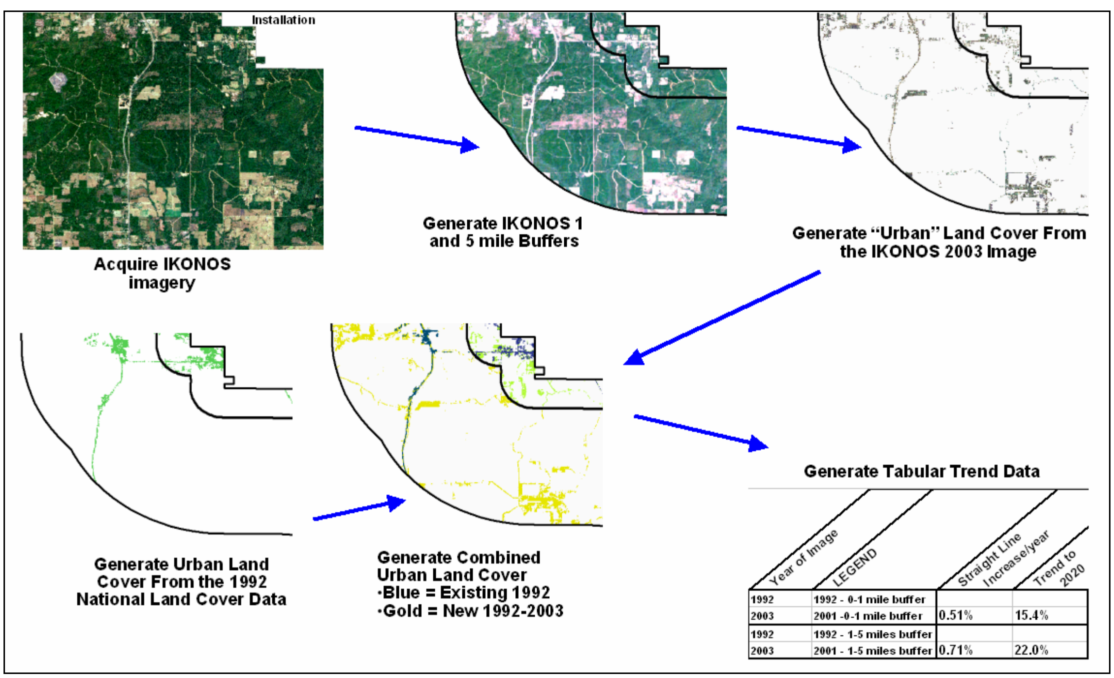


Figure 1. Seven major steps of the Protocol.



Year of Image	LEGEND	Straight Line Increase/year	Trend to 2020
1992	1992 - 0-1 mile buffer		
2003	2001 -0-1 mile buffer	0.51%	15.4%
1992	1992 - 1-5 miles buffer		
2003	2001 - 1-5 miles buffer	0.71%	22.0%

Figure 2. Visual interpretation of the Protocol steps.

Software Used

- ESRI ArcGIS 8.1 with extensions Spatial and Image Analyst
- ERDAS Imagine 8.6
- Microsoft Excel 2000
- WinZip Version 8.1

Required Data

- National Land Cover Data for each installation
  (Six installations were in areas for which no NLCD were available. The comparable protocol for these is given in Appendix A)
- Installation Visualization Technology (IVT) Ikonos Image
- Installation Boundaries
- Roads from Census data
- Contextual Information

Required Standard Directory Structure and File Naming Conventions

The analysts were required to follow a standard directory format and place files in a central location, so that everyone knew where to look for data they needed to access and so that anyone looking at this report would be able to find the resulting data layers on the disk if they have access to the data files. The instructions were to make a directory titled with the installation name. All general data was to be saved within this level, including the .mxd file for that installation. Researchers then made three subdirectories; one for all NLCD related data, one for all Ikonos imagery and derived data, and one for the roads data (derived from Census data). Layers that are combinations of the Ikonos, NLCD, and Census data were stored in the general installation level directory.

```
          InstallationName
                  |     [save .mxd file here]
    ---------------------------------------
    |             |             |
  NLCD         IKONOS        Census
```

This standard directory structure allowed all the data associated with an installation could be archived in a single command. It was also the standard procedure to allow no spaces in file names because occasionally ESRI GRID file names would not be recognized if they contained spaces.

Within this document, the following conventions are established:

"Save in installation directory" means save in Drive:/InstallationName

"Save in Ikonos directory" means save in Drive:/InstallationName/Ikonos

"Save in NLCD directory" means save in Drive:/InstallationName/NLCD

"Save in Census directory" means save in Drive:/InstallationName/Census

The narrative for the Protocol's 7 Steps is provided below as directions in present tense to the analyst carrying out the steps. All the steps need not be done in order. For example, while waiting for the Ikonos images, the research team began to format the NLCD data layers (Step 5) and to define the Study Area (Step 2).

Protocol Outline

Step 1: Acquire Ikonos imagery and set window defaults

- Step 1.1 Set up Required Directory Structure
- Step 1.2 Make boundary file for your installation
- Step 1.3 Identify which imagery tiles cover your installation
- Step 1.4 Determine if imagery coverage is adequate

Step 2: Determine Extent of Study Area

- Step 2.1 Generate Installation buffers
- Step 2.2 Optional: Define Rectangular Study Area
- Step 2.3 Make a rectangular grid that coordinates with the location and resolution of the Ikonos images
- Step 2.4 Convert the buffer shape file into a grid file at the final resolution.
- Step 2.5 Make the roads buffer mask

Step 3: Generate Working Ikonos Study Area

- Step 3.1 Subset the portion of the images to be used or define AOI (Area of Interest)
  - Step 3.1a Option 1: ESRI Image Analysis
  - Step 3.1b Option 2: ERDAS Imagine8.6
- Step 3.2 Mosaic the subset images into one
  - ESRI Step 3.2a Mosaic the subset images into one
  - ERDAS Step 3.2b Mosaic the subset images into one

Step 3.3 Subset the portion of the mosaic to the 5-mile buffer

ESRI Step 3.3a Subset the portion of the mosaic to the 5-mile buffer

ERDAS Step 3.3b Subset the portion of the mosaic to the 5-mile buffer

Step 4: Generate "Urban" Land Cover from the Ikonos Image

Step 4.1 Use unsupervised classification with 16 categories to generate a classified image of land cover from Ikonos image for the study area.

Step 4.2 Reclass the categories to Urban

Step 4.3 Clip the preliminary urban category file by the roads buffer

Step 4.4 Let the unsupervised classifier reclassify only those areas in the preliminary-urban mask.

Step 4.5 Urban into a grid

Step 4.6 Preliminary Quality Evaluation

Step 5: Generate Land Cover From the NLCD

Step 5.1 Obtain the NLCD for the state

Step 5.2 Import to TIFF Format

Step 5.3 Reproject Images

Step 5.4 Clip NLCD Grid to the Study Area

Step 5.5 Reclass the NLCD data into an urban category layer

Step 5.6 Generate an exclude mask from the NLCD for areas that will never be developed land

Step 6: Generate Trend Tabular Data

Step 6.1 Make a combined grid file of 1992 and 2001 urban

Step 6.2 Calculate unique values for different urban growth degrees at different times depending on the buffer

Step 6.3 Export the data to an Excel file, populate the table and generate the trend data in Microsoft Excel

Step 6.5 Save Table to Trend directory

Step 7: Quality Control and Wrap up

Step 7.1 Complete Quality Evaluation

Step 7.2 Wrap Up

Protocol Steps

Step 1: Acquire Ikonos imagery and set window defaults

Step 1 General description: Begin with acquiring the imagery. For this research project, the research team contacted the IVT office where the imagery was being collected, and either received it by mail written onto DVD (digital video disk) or downloaded it by FTP (File Transfer Protocol). The team set up a working ArcMap Window. Once an analyst was assigned to do the tasks for an installation, but before the imagery arrived, Step 5 was often completed.

Step 1.1 Set up Required Directory Structure

Where to store installation data - To support the project, the team purchased three 300-gigabyte hard disks. Installations east of about 104 degrees west longitude were stored on the disk called TABS1. Installations west of about 104 degrees west longitude were stored on TABS2. To make this clear, the USA_portable.mxd file was distributed with a graphic showing the split. Installations assigned to the ERDC CRREL staff were mostly smaller eastern installations so their data all fit on the third hard disk.

Set up installation working directory per standard structure:

```
        InstallationName
                   | [save .mxd file here]
     ----------------------------------
     |             |                 |
   NLCD        IKONOS            Census
```

Set up context - To be compatible between different installations, set up an accessible version of the USA_portable directory on a disk at the same level as the Installation_Name level. To create a map document (.mxd file) for each installation, click on the USA_portable directory, double click on the file usa_instals.mxd. This will bring up an ArcMap window with contextual data. ***IMMEDIATELY*** go to the File menu item and choose Save as…. Navigate to your InstallationName directory and save it as InstallationName.mxd. Whenever you work on this installation, this will be your working document. If someone else needs to work on this installation, this is the document they will call up. It is also what will be used to present your work and in the end, to document your procedure.

ArcMap: When you click on the InstallationName.mxd, ArcMap will come up. To set the default tool bars within ArcMap:

From View select Toolbars. Choose the following toolbars (optional toolbars are in parentheses):

Main Menu
Standard
Tools
(Draw)
(Effects)
(Layout)
Spatial Analyst
Editor
Image Analyst (Experience suggests that you should not save while this toolbar is open. It is recommended that you have this toolbar open only when you are using it and that you remove it before you save your .mxd file.)

If the Layer: input box in either the Spatial Analyst or the Image Analysis toolbars is grayed out, this means you must tell ArcMap that you want it:

Go to the Tools menu
Choose Extensions
Click to place a checkmark next to both the Spatial Analyst and the Image Analysis boxes. Close.

Once the ArcMap window from the InstallationName.mxd is ready, you may want to change the way the layers are presented. For example, the default display mode for the installation boundaries will have the installation area filled in with an opaque color. To make modifications on how layers are presented, change the Symbology. The following is an example for the boundary, but the method is similar for other layers.

In the TOC (Table of Contents) double click on the layer name (e.g., Boundary).
The Layer Properties menu will appear. Click on the tab for Symbology.

Within the Symbol box, Click on the rectangle showing the color and outline. The Symbol Selector box will appear. Under Options, click on the Fill Color color sample square. To remove the current fill color click on the No Fill selection. Similarly you can modify the other properties from this window to suit your purpose. For example, the outline color can be changed to black and widened to an Outline width of 2. When done, click on OK, then OK again.

Click on the tab for Display.

From here you can set the Transparency to be 60% so that you can look through the installation and see the Ikonos image behind it.

Step 1.2 Make boundary file for your installation

The usa_instals.mxd file includes the official TABS boundaries of all the installations. It is called Installation_Boundary.shp. You need to pull out your specific installation. To do this:

Right click on the Installation_Boundary.shp. On the pop-up menu, click on the Attribute Table option. At the bottom of the Attributes of Installtion_boundary window, click on the Options down arrow and choose Find and Replace. In the Find and Replace window on the Find what box, enter only the "core" portion of your installation's name. Make sure that Text Match: is set to Any Part, Search is set to All, and the Match Case and Search Only Selected Field(s) are NOT checked. Press Find Next. The entry for your installation should come up. Press Find Next again. If you find another line with your installation listed, you will have to select and save both/all sections according to the following procedure. On the Attributes of Installation_boundary window, click on the furthest left gray button to Select the entire row. For each additional line that includes your installation, you will need to hold down the shift key and click on the furthest left gray button to Select that entire row in addition to the first row. Select all rows that make up the extent of your installation. Back in the main ArcMap menu, click on Selection menu and then chose Zoom to Selected Features. Your installation should be centered in the window with the boundaries highlighted in blue.

Now you need to save the selected polygons as an individual .shp file for your installation. Right click on the Installation_Boundary.shp in the TOC. On the pop-up menu chose Data. (**Beware!!** The option "Save as layer file" is the wrong choice.) Now choose Export Data. In the Export Data window, Export: should be Selected features, choose the option Use the same Coordinate System as the data frame (i.e., Geographic WGS84; WGS is World Grid System) and for the Output Shapefile or feature class, navigate to your installation directory and save as boundary.shp. ArcMap will process for a minute then ask if you want to display it on your current map document. Reply "yes," of course.

Step 1.3 Identify which imagery tiles cover your installation

Access Ikonos Imagery from central disk site.

Images are not named by installation, but by their latitude/longitude locations. For example: FB_5M_MOSAIC1_110w30na.tif refers to an image that is located roughly 110 degrees west longitude by 30 degrees north latitude. It is the "a" tile of a group of tiles (in this case, including "b," "c," and "d"). In ArcMap, use the Identify Button to left click on your installation. The data window that pops up will include a line with the image name on it (similar to FB_5M_MOSAIC1_110w30na.tif). This is the tile that covers your installation. It is likely that several tiles will be needed

to cover your study area. Find those that seem to cover your installation. You do not need to copy them to your work area. However, when you start saving Ikonos-derived images and grids, save them in the Ikonos directory for your installation.

Determine projection of the Ikonos imagery (see example metadata .txt file in box on next page). The official geographic projection for all work on this project is Geographic WGS84. The projection of all data frames should be in this projection. All databases generated should also be in this projection because when using Spatial Analyst, unexpected results can be derived when generating new maps. (Arc GIS 8.3 does projections FOR DISPLAY on the fly. FOR ANALYSIS it is best to generate information in the native projection of both the originating data and the frame.)

Use ArcCatalog to find the .txt file for your images. Click on the file name. On the Contents tab, you should see Band_1, Band_2, and Band_3. The Preview tab should show the image (usually in a GeoTiff format). On the Metadata tab you should see that the Coordinate System: is Geographic. Under the Spatial Reference Information, you should see a line that says: Geographic coordinate system name: GCS_WGS_1984. All databases generated should also be in this projection.

Sample Metadata file for Space Imaging product

```
Image
File        : FB_5M_MOSAIC1_096w48na.tif
Projection   : Geographic
Datum        : WGS84
Ellipsoid    : WGS84
GSD          : 0.000040003200000 Degrees
Upper Left   : -96.000000, 48.000000
Lower Right  : -95.500000, 47.500000
Coordinates refer to the center of the pixel
Geographic coordinates for corners
Upper Left   : -96.000000 deg lon, 48.000000 deg lat
Upper Right  : -95.500000 deg lon, 48.000000 deg lat
Lower Right  : -95.500000 deg lon, 47.500000 deg lat
Lower Left   : -96.000000 deg lon, 47.500000 deg lat
Image Size   : 12500 samples, 12500 lines, 3 bands
Produced by  : Space Imaging
```

Step 1.4 Determine if imagery coverage is adequate

In some cases the 5-mile buffer and study area will extend beyond the imagery available. Make an estimate of a 5-mile buffer around the installation. If you do not have sufficient Ikonos imagery to allow you to create a rectangular grid, then you must request the missing imagery immediately – lack of the imagery will impede the rest of the processing until the data is in hand. In this case, IMMEDIATELY re-request from the IVT office per Appendix B to see if the additional areas that are needed are available.

Step 2: Determine extent of study area

Step 2 General description: You need to define the extent of the work area. This step should be based on a combination of the installation boundaries and the extent of the available imagery.

Step 2.1 Generate Installation buffers

From the installation boundaries file generate two buffers:

Buffer1 – 0 to 1 mile

Buffer2 – 1 to 5 miles

Make sure the analysis is being done in the Ikonos projection. Finally, generate a rectangular area to be the Study Area extent.

From Tools select Buffer Wizard:

You want to Buffer: Features of a layer -> choose Boundary.shp (the shape file you just created)

Create Buffers as multiple buffer rings (Number of Rings = 5, Distance Between rings = 1). The Buffer distance, Distance unites are: Miles. Then click Next.

Buffer output type: Dissolve barrier between: no.

Create buffers so they are: only outside the polygons

Save the buffer -> In a new layer -> Bond_Buf_5.shp

Remove the extra boundaries.

From the Editor toolbar select Start Editing.

For Which folder, chose the one that contains the Bond_Buf_5.shp file.

On the Editor toolbar, the Target is the Bond_Buf_5.shp file, the Task is Modify Feature.

On the Table of Contents (TOC) frame, right click on Bond_Buf_5.shp and chose Open Attribute Table.

Each buffer distance has its own Feature ID. Determine which relates to the 1-mile buffer by selecting different records until the 1-mile buffer is highlighted (FromBufDst field has a value of 0). Once identified, place a value of 1 in the ID field. Place a value of 2 in all the other ID fields. Click in another data location beside the last you entered. Under Options, Clear Selection.

On the Editor toolbar, click Stop Editing, then answer Yes to Do you want to save your edits?

On the Main Menu, click Tools, then Geoprocessing Wizard.

Chose Dissolve features based on an attribute.

1. Select the input layer to dissolve: Bond_Buf_5
2. Select an attribute on which to dissolve: ID

3. Specify the output shapefile: Bond_Buf15

For Choose one or more additional fields…, click on the FromBufDst and check Minimum and Maximum, then Finish.

The new Bond_Buf15 file will appear on the TOC.

Remove the intermediate file Bond_Buf_5 by right clicking on its name in the TOC and selecting Remove.

The new Bond_Buf15 file will be used throughout this analysis and the results depend on it being an accurate delineation of the extent of the imagery being used. Too often the imagery available is less than the extent of the 5-mile buffer. This means that the team modified Bond_Buf15 into a new file Bond_Buf15_trunc that was used where appropriate in place of Bond_Buf15 throughout the rest of this report.

You need to modify Bond_Buf15 to reflect only area for which imagery data is available. Known examples include:

1. Imagery only goes out to 2 miles. Digitize an outline that includes the entire imagery available and union, clip, or intersect it with Bond_Buf15. You can think of this as bond_buf12, but for consistency it is named Bond_Buf15_trunc.
2. One panel of imagery is missing.
3. A “spike” of imagery is missing between the satellite paths.
4. Imagery is unreadable or a portion is from a different season.

Digitize an outline that includes the entire imagery available and union, clip, or intersect it with Bond_Buf15. Follow a procedure similar to the variation given in Appendix C. The bottom line is that you end up with an edited outline that includes all the imagery available (by editing, unioning, clipping, or intersecting it to get Bond_Buf15_trunc) that represents the coverage of the imagery if it is less than Bond_Buf15. It is important that in the attribute table, there is a Field, possibly called Id, that shows a feature value=1 for the polygon that is the 0- to 1-mile buffer and a value=2 for the feature for the 1- to 5-mile buffer.

Changes in the Bond_buf15.shp to Bond_buf15_trunc.shp will have important direct effects on these steps:

Step 2.4 Convert the buffer shape file into a grid file at the final resolution – in generating Buf15_G

Step 2.5 Make the roads buffer mask – in generating rds_clip_5mile_buf

Step 3.3 Subset the portion of the mosaic to the 5-mile buffer – in generating Ikonos_Buf15.img

Step 4.1 Use an Unsupervised classification with 16 categories to generate a classified image of land cover from Ikonos image for the study area – in generating Ikonos_class16.img

Step 6.4 Populate the table and generate the trend data in MS Excel in generating:
Count of Undevelopable Land
% Undevelopable land is the Count of Undevelopable Land
1992 Urban Land Use Counts
Length of Roads within 1 mile
Towns within 1 & 5 miles & Town Population within 5 miles.

It may also have secondary effects on areas not generated directly from Bond_buf15.shp but from secondary products. If you have a non-standard Bond_buf15.shp, you must redo it as Bond_buf15_trunc.shp and check those steps listed above to ensure a correct result. Also review those secondary products to make sure they are correctly derived. This is not optional as the cell counts derived in Step 6 are based on Bond_buf15.shp.

Step 2.2 Optional: Define Rectangular Study Area:
Variation: In some cases the initial study area will extend beyond the imagery available. In this case, request additional images from the IVT office areas that are needed. If not, you will need to modify the Study area to reflect only the area for which imagery data is available. Follow the procedure in Appendix C.

Make a shape file that is a rectangle slightly larger than the largest portion of the 5-mile buffer.
In ArcCatalog click on the directory name in which you are working.
On the main menu, click File, then New, then Shapefile.
To Create New Shapefile,
The Name will be StudyArea
The Feature Type will be Polygon
In the Spatial Reference box, click Edit
In the Coordinate System click the Import Button
Select the installation boundary shape (check to make sure this is the same as the standard frame projection). Click Apply.
Check to make sure you have the right projection, then click OK.
Click OK at the bottom of the Create New Shapefile box.
Click and drag the new StudyArea file into the ArcMap window.

In ArcMap, click on the Edit toolbar and choose Start Editing
Choose the directory to edit in which the StudyArea file resides.
On the Editor toolbar, the Target is the StudyArea.shp file, the Task is Create New Feature.
Click the Editor Down Arrow and choose More Editing Options and then choose the Advanced Editing option to display an additional toolbar.

On the Advanced Editing toolbar, click on the Rectangle Tool icon and in the ArcMap window; make a rectangle about 1 or 2 miles beyond the 5-mile buffer.

Optional: On the Editor toolbar, change the Task to Modify Features
Make sure the Edit Tool arrow is selected, move it over one of the edge lines (not in the interior) and right click. Select Properties to bring up the Edit Sketch Properties window.
In the Edit Sketch Properties window you can directly change the values of the X,Y corner points to make them more closely coordinate with even values in the projection you are using.
Click Finish Sketch and dismiss the Edit Sketch Properties window.

On the Editor toolbar, click the Editor down arrow, then Stop Editing, then answer Yes to Do you want to save your edits?

Step 2.3 Make a rectangular grid that coordinates with the location and resolution of the Ikonos images.

Under the Spatial Analysis toolbar, click the down arrow and choose Options
On the General tab, set Analysis mask to StudyArea
NOTE: because the frame is in the desired projection, you should never need to change the default setting of Analysis Coordinate System:. Always leave as Analysis output will be saved in the same coordinate system as the input (…
On the Extent tab, set Analysis Extent to StudyArea and Snap Extent to: <None>
On the Cell Size tab, set Analysis cell size to Same as Layer "the Ikonos image you will be using"
Click OK to submit these to the system.

Under the Spatial Analysis toolbar, click the down arrow and choose Raster Calculator
In the Raster Calculator evaluation box, enter the value 1.
Click the Evaluate button.
The result should appear on the map and in the TOC as Calculation. Right click on Calculation and choose the Make Permanent option. In this window navigate to the installation directory and save the file as StudAreaG and for Save as type: choose ESRI GRID. Click the Save button.

In the TOC slowly double click on the name Calculation and rename it StudAreaG. Double left click on the name and on the Symbology tab, within the Show box, highlight Classified. In the Classification box, make the Classes equal 1. Click OK.

NOTE: For unknown reasons, saving a calculation using this procedure will sometimes cause ArcMap to crash. If this happens, there is a work-around:

First, create a temporary folder within the installation directory. This folder will be used in all subsequent calculations. To do this, go to the installation directory in ArcCatalog. In the Contents window, right click and choose New > Folder. Rename this new folder Temp_calc.

Under the Spatial Analysis toolbar, click the down arrow and choose Options.

Under the General tab, set the working directory to this new folder Temp_calc. Click OK.

Go back to repeat the calculation using the Raster Calculator.

When the resulting calculation appears in the TOC, this time, double click the calculation, and select the Source tab in the Layer Properties dialog box.

In the Data Source field, there will be information about the raster file you just created. Take note of the name of the Raster your calculation represents. Because this calculation has not been made permanent yet, this name will be CALCsome_number. Leave the Layer Properties dialog box open.

Then in ArcCatalog, navigate to the temporary folder you created.

Click View > Refresh at the top of the ArcCatalog window. You should now see the temporary CALC file you generated. Copy this file and paste it into the Ikonos folder. Rename the file StudAreaG.

Back in ArcMap, click on the Set Data Source button in the Layer Properties dialog box. Navigate to the Ikonos folder of your installation, highlight the StudAreaG file, and click Add, to set it as the new source data for this layer. Click OK in the Layer Properties dialog box.

You may now rename the calculation in the TOC: Slowly double click on the Calculation and rename it StudAreaG. Experience has shown that this work-around may be necessary for all subsequent raster calculations for a given installation.

End of NOTE.

Step 2.4 Convert the buffer shape file into a grid file at the final resolution.

Under the Spatial Analysis toolbar, click the down arrow and choose Options

On the General tab, set Analysis mask to Bond_Buf15

On the Extent tab, set Analysis Extent to Bond_Buf15 and Snap Extent to: <None>

On the Cell Size tab, set Analysis cell size to 0.00010 (the final resolution)

Click OK to submit these to the system.

Under the Spatial Analysis toolbar, click the down arrow and choose Convert and choose Features to Raster

On the Features to Raster window

For Input features enter the Bond_Buf15 file name.

For the Field, use the field (possibly called Id) that shows whether the polygon is in the 1-mile buffer (value=1) or the 1- to 5-mile buffer (value=2).

Output cell size: should be the same as the final target value of 0.0001 (it should default to the value you set in Options above).

For Output raster: navigate to the installation directory and name the new file Buf15_G and Save as type: ESRI GRID.

Press the Save button.

Click the OK button.

The result should appear on the map and in the TOC as Buf15_G. Right click on Calculation and choose the Open Attribute Table option. In this window, check to make sure that the buffer identities are correctly generated by alternately selecting either 1 or 2. When satisfied, click on Options and then choose Clear Selection. Dismiss the table.

Double left click on the name Buf15_G and when the Layer Properties box appears, on the Symbology tab. Within the Show box, highlight Unique Values. Under the Label column, label 1 as the 0- to 1-mile category and label 2 as the 1- to 5-mile category. Click OK.

Step 2.5 Make the roads buffer mask:

Acquire the commercial GDT (Geographic Data Technology) Dynamap/2000 Street Network data (July 2003).

Generate needed roads file:

From the several roads files, the one that includes all the roads has a name like: STATEABBREVIATIONcountynameS. Use ArcCatalog to load it to your ArcMap window.

Note: the registration is not perfect. Although the Datum's are different than our standard, reprojecting makes no difference at all. Therefore, use file as is.

If you need more than one county, merge them here. If not skip to the following Clip the count roads to the 5-mile buffer section.

On the Main Menu, click Tools, then Geoprocessing Wizard.

Chose Merge layers together, then Next>.

1. In the Select at least two layers to merge window put a check next to all the polyline layers that cover your study area.
2. For Use fields from: Select one of the polylines.

Specify the output shapefile: Navigate to your installation's Census directory and name the file: STATEABBREVIATIONcountynameS

Then click the Finish button.

The new STATEABBREVIATIONcountynameS file will appear on the TOC.

Note: For locations that are largely desert or barren, using all roads may include too much area. If this seems to be the case, consider using only those road files that are major or named roads (i.e., in the attribute table for STATEABBREVIATION-countynameS, sort by Road Name. Then delete all roads without a name). This will eliminate dirt trails in many locations that are unsuitable for development.

Variation: Sometimes it is also wise to prune out even named roads. If many roads have no development, there is no sense in keeping them.

Clip the county roads to the 5-mile buffer:

On the Main Menu, click Tools, then Geoprocessing Wizard.

Chose Clip one layer based on another, then Next>.

Select the input layer to clip: STATEABBREVIATIONcountynameS

Select a polygon clip layer: The Bond_Buf15 file

Specify the output shapefile: rds_clip_5mile_buf in the Census directory.

Then click the Finish button.

The new rds_clip_5mile_buf file will appear on the TOC.

Buffer the roads:

From Tools select Buffer Wizard

You want to Buffer Features of a layer -> rds_clip_5mile_buf. Click Next>

Create Buffers as At a specified distance. The distance will be 150 meters. The Buffer distance, Distance units are meters. Then click Next.

Buffer output type: Dissolve barrier between: Yes.

(Create buffers so they are: is grayed out as not available for this specification.)

Save the buffer -> In a new layer -> navigate to the Census Directory and save as: rds_clip_5mile_buf_150mbuf.shp.

The roads buffer will be used in Step 4.

Step 3: Generate working Ikonos study area

Step 3 General description: Several Ikonos images are usually required to cover an installation. In addition, you may want to use only that portion needed to carry out the tasking, so sew together the images you need and extract only the area that will be required for the analysis. This will also save computational time in the following steps.

1. Subset the portion of the images to be used or define AOI
   ESRI ArcGIS Version- Step 3.1a Option 1: ESRI Image Analysis
   ERDAS Imagine Version - Step 3.1b Option 2: ERDAS Imagine8.6:
2. Mosaic the subset images into one.
   ESRI ArcGIS Version - Step 3.2a Mosaic the subset images into one
   ERDAS Imagine Version - Step 3.2b Mosaic the subset images into one
3. Subset the portion of the mosaic to the 5-mile buffer
   ESRI ArcGIS Version - Step 3.3a Subset the portion of the mosaic to the 5-mile buffer
   ERDAS Imagine Version - Step 3.3b Subset the portion of the mosaic to the 5-mile buffer.

Subset the portion of the images to be used

End using the Spatial Analysis, Start using the Image Analysis.

Step 3.1a Option 1: ESRI Image Analysis:

Under the Image Analysis toolbar, click the down arrow and choose Options

On the General tab, set Analysis mask to Stud_area_G. This way only those areas within the study area will be considered.

On the Extent tab, set Analysis Extent to Stud_area_G

On the Cell Size tab, set Analysis cell size to Same as Layer Oneo theIkonosImages.img

On the Preferences tab, set the Resample Using: to Nearest Neighbor.

Click OK to submit these to the system.

Under the ESRI Image Analysis toolbar, click the down arrow and choose Data Preparation, then the Subset Image option.

In the Subset Image window

For the Input Image: click the down arrow and choose the image you wish to cut to the study area size

For Select desired band numbers: Click in the number area and 1:3 will pop up. If not, enter 1:3

For the Output Image, navigate to the Ikonos directory and name the new image: Ikonos_studtile#. (The # refers to which of the different Ikonos images you are subsetting. For large installations, the tile number can be large. If one image covers the entire study area, then you can skip the next step (mosaicing) and directly name the file Ikonos_stud_area.). Save as type will be ERDAS IMAGINE. Press the Save button.

Press the OK button.

Repeat this process for each image that will make up the study area.

Step 3.2a Mosaic the subset images into one.

If more than one image is required to make up the study area, you must mosaic the subset images into one.

Under the Image Analysis toolbar, click the down arrow and choose Options

On the General tab, set Analysis mask to StudyArea (or to the Tuncated StudyArea file)

On the Extent tab, set Analysis Extent to StudyArea and Snap Extent to: <None>

On the Cell Size tab, set Analysis cell size to Same as Layer “the Ikonos image you will be using”

On the Preferences tab, set the Resample Using: to Nearest Neighbor.

Click OK to submit these to the system.

Sometimes the computer internal settings need to be reset at this point. To do this, remove the Image Analysis toolbar, Save the map document and exit ArcMap. Then put up the ArcMap document, replace the Image Analysis toolbar and continue.

Mosaic the subset images into one

In the TOC select (highlight) all those subset images that need to be mosaiced. In the Image Analysis toolbar, for Model Types: choose the Ikonos option.

Under the Data Prep toolbar button, click the Mosaic Images option.

In the Mosaic Tool window

Under the Edit menu select Add Images…

Method is Individual File. Press the Open File icon and in the Image Filename box, navigate to the installation Ikonos directory. Change the Files of type: to TIFF and choose the files that make up the study area. You can chose more than one by holding down the SHIFT key while clicking on the correct file names. Click OK, then Add and Close if you have them all.

For the Output Image, navigate to the Ikonos directory and name the new image called: Ikonos_stud_area. Save as type will be ERDAS IMAGINE. Press the Save button.

Press the OK button.

Check to make sure the resulting image is exactly the same as the component images by:

One after the other, double click on the names of both the input images and the resultant images and under the Symbology tab, set the Stretch to None. Press OK. Zoom into the edge area between the input images and resultant and make sure that the colors and spatial locations are correct. You might want to compare the road location to the image to make sure they are in the right place.

Step 3.3a Subset the portion of the mosaic to the 5-mile buffer.

Under the ESRI Image Analysis toolbar, click the down arrow and choose Options

On the General tab, set Analysis mask to Bond_Buf15. This way only those areas within the boundary will be analyzed.

On the Extent tab, set Analysis Extent to Bond_Buf15

On the Cell Size tab, set Analysis cell size to Same as Layer Ikonos_stud_area.img

On the Preferences tab, set the Resample Using: to Nearest Neighbor.

Click OK to submit these to the system.

Under the Image Analysis toolbar, click the down arrow and choose Data Preparation, then the Subset Image option.

In the Subset Image window:

For the Input Image: click the down arrow and choose the image you wish to cut to the 5-mile buffer size

For Select desired band numbers: Click in the number area and 1:3 will pop up. If not, enter 1:3

For the Output Image, navigate to the Ikonos directory and name the new image: Ikonos_Buf15. Save as type will be ERDAS IMAGINE. Press the Save button.

Press the OK button.

End Option 1

Step 3.1b Option 2: ERDAS Imagine8.6:

First define subset of the study area as an AOI

1. Open two Viewers. In Viewer #1 you will need to display the Ikonos images for the installation. In the Select Layers to add dialog box, change the Files of type: to TIFF and choose the files that make up the study area. (You might be able to

choose more than one by holding down the SHIFT key while clicking on the correct file names.) Click OK.

2. In Viewer #2, first display one of the Ikonos tiles (this ensures that the projections in both viewers are the same), then display the vector layer, StudyArea, from which you want to create the AOI. Images in Viewer #1 must be in the same map projection as the StudyArea vector file in Viewer #1.
3. In Viewer #2, select (click on) the StudyArea file. The StudyArea turns the selection color (probably yellow).
4. In the menu bar of Viewer #1, select AOI | Copy Selection to AOI...
5. In the menu bar of Viewer #1, select View | Arrange Layers. In the Arrange Layers Viewer #1, right click on the AOI layer and choose Save layer. In the Save AOI as: window, navigate to the installation directory and save it as StudyArea.aoi. Click OK, then OK again to dismiss the Save AOI as: window.

Step 3.2b Mosaic the subset images into one:

In Viewer #1, under the Raster menu item, click the Mosaic Images option.

In the Mosaic Tool window, all the files will be displayed.

Under the Edit menu select Set Overlap Function. No Cutline Exits. For the Select Function select Average. Click the Apply, then the Close buttons.

Under the Edit menu select Output Image Options. For Define Output Map Areas(s) choose User-defined AOI.

For Output Multiple AOI Object to: A Single File. Press the Set Output AOI bar. Choose AOI from AOI File. Navigate to your installation directory and select studyarea.aoi. Press OK.

Select the default (do NOT Change output Map Projection) and for Output Cell Size: (dd) select 0.000040 while Output Data Type: is Unsigned 8 bit. Click OK.

On the menu for the Mosaic Tool, click on Process, then Run Mosaic.

In the Run Mosaic box, for the Output File Name, navigate to the Ikonos directory, save as Files of type: Image, and name the new image Ikonos_Stud_Area. Click OK.

Check the Output a Common Look up Table, Ignore Input Values of 0, make sure Output background Value is 0 and do NOT Compress. Then press OK.

Press the OK button. Processing will take a while.

Step 3.3b Subset the portion of the mosaic to the 5-mile buffer:

Define subset of the 5-mile buffer as an AOI.

1. Open two Viewers. In Viewer #1 display the Ikonos_stud_area.img for the installation.
2. In Viewer #2, first display the Ikonos_stud_area.img (this ensures that the projections in both viewers are the same), then display the vector layer, Bond_Buf15, from which you want to create the AOI. Images in Viewer #1 must be in the same map projection as the StudyArea vector file in Viewer #2.
3. In Viewer #2, select (click on, then shift & click) all of the rings of the Bond_Buf15 file. The Bond_Buf15 turns the selection color (probably yellow).
4. In the menu bar of Viewer #1, select AOI | Copy Selection to AOI...
5. In the menu bar of Viewer #1, select View | Arrange Layers. In the Arrange Layers Viewer #1, right click on the AOI layer and choose Save layer. In the Save AOI as: window, navigate to the installation directory and save it as Bond_buf15.aoi. Click OK, then OK again to dismiss the Save AOI as: window.

Subset the portion of the mosaic to the 5-mile buffer:
Under the Data Preparation menu item, click the Subset Image option.
In the Subset Image Tool window:
For the Input File Name navigate to the Ikonos directory, choose the image Ikonos_stud_area.
For the Output File Name, navigate to the Ikonos directory, save as Files of type: Image, and name the new image Ikonos_buf15.
For the Data Type set:
Input: Unsigned 8 bit
Output: Unsigned 8 bit
Output: Continuous
For Output Options set
Select Layers: 1:3
Click on the AOI button on the bottom.
In the Choose AOI window, for the Select an AOI Source: click on AOI File option.
In the Select the AOI File box, navigate to the installation directory, and choose the Bond_buf15.aoi file. Click OK.
Press the OK button to start the sub setting.

<u>End Option 1</u>

Step 4: Generate "urban" land cover from the Ikonos image

Step 4 General description: Determine from the imagery which are the locations that are most likely urban. To do this, run the image through an unsupervised classification routine. From this image, choose those categories that best fit urban. Using this urban definition as a mask, do another unsupervised classification but only on those areas that are most likely to be urban.

Use an Unsupervised classification with 16 to 100 categories to generate a classified image of land cover from Ikonos image for the study area.

<u>*Option 1: ESRI Image* Analysis (very slow):</u>

Step 4.1a Start using the Image Analysis

On the Image Analysis toolbar, in the Layers: window, click the down arrow and choose Ikonos_Buf15.img, then for the Model Types: window, click the down arrow and choose the Ikonos option.

Under the Image Analysis toolbar, click the down arrow and choose Options

- On the General tab, set Analysis mask to Bond_Buf15. This way only those areas within the boundary will be analyzed.
- On the Extent tab, set Analysis Extent to Ikonos_stud_area.img
- On the Cell Size tab, set Analysis cell size to Same as Layer Ikonos_stud_area.img
- On the Preferences tab, set the Resample Using: to Nearest Neighbor.
- Click OK to submit these to the system.

In the *Image* Analysis window, click the down arrow and choose Classification, then the Unsupervised Classification option.

- In the Unsupervised Classification window
  - For the Input Image: click the down arrow and choose the Ikonos_Buf15.img layer.
  - For Desired Number of Classes: fill in the value 16 (initially).
  - For the Output Image, navigate to the Ikonos directory and name the new image: Ikonos_class16.img*. Save as type will be ERDAS IMAGINE. Press the Save button.
  - Press the **OK** button.

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* The appropriate number of classes was found to be highly variable. The more classes, the more work is required. Experience suggests that areas of desert, barren areas or agricultural fields would require more classes. Most analysts tended toward 32 classes. To facilitate communication among team members, the name Ikonos_Class16 was used independent of the actual number of classes generated.

<u>End Option 1: ESRI Image Analysis:</u>
<u>Begin Option 2: ERDAS Imagine 8.6:</u>

Step 4.1b Start using the *ERDAS Imagine.*
On the main tool bar click the Classifier (or Data Prep) button. On the Classification menu, choose Unsupervised Classification.

In the Unsupervised Classification (Isodata) window for the Input Raster File navigate to your installation Ikonos directory and choose Ikonos_Buf15.img. For the Output Files of Type, choose GRID Stack (*.stk). For File Name: input I_Class16_g. Press OK twice. Uncheck Output Signature Set.

For Number of Classes: enter 16.

Take the defaults for the rest:

Initialize from Statistics
Maximum Iterations: 6
Convergence Threshold: 0.950
Skip Factors: x=1, y=1

Press OK

Warning boxes may appear. Just click OK so the processing can continue.

You will be informed when the processing is finished.

<u>End Option 2: ERDAS Imagine 8.6:</u>

Examine this classified image closely to determine which two or three categories coordinate closely with residential and commercial development types.

Guidance: In this first classification, there can be a good deal of confusion between developed uses and barren land/soil. In a more humid environment, it is assumed here that land is barren because of human activity; therefore this is a part of the encroachment on which you are focusing. On the other hand, in an arid environment, barren land is not necessarily a sign of human activity.

If it looks like 16 classes are inadequate to cleanly distinguish urban vs. non-urban, redo Step 4.1 with 32 to 100 classes so that the categories are distinctive.

The next step generates an "urban" mask. There are several reasons for generating a mask of urban land uses for the time of the Ikonos image, roughly 2003. First, it will provide a conservative evaluation of the encroachment that is occurring. You may miss counting areas that were "urban" in 1992. However, by this restrictive technique, you end up counting as urban only those areas that are included in the 2003 "urban" mask. That is, for the 1992 urban value, count only those areas that were urban in both 1992 and 2003. Second, this procedure ensures a single direction for development (i.e., greater development as time goes on). Third, the proce-

dure has the desired advantage of mitigating the great difference in resolution between the Ikonos imagery (5 meters-on-a-edge/pixel) and the NLCD (30 meters-on-an-edge/pixel).

To implement these concepts, fine-tune the identification of the 2003 urban areas. In general the procedure is to develop a mask from the most urban categories from the previous step, then let the unsupervised classifier reclassify only those areas in the preliminary-urban mask. By testing each of the resulting categories, you can determine the best dividing line between categories that are urban (yellow in Figure 3) and non-urban (usually barren) which are represented as light pink in Figure 3.

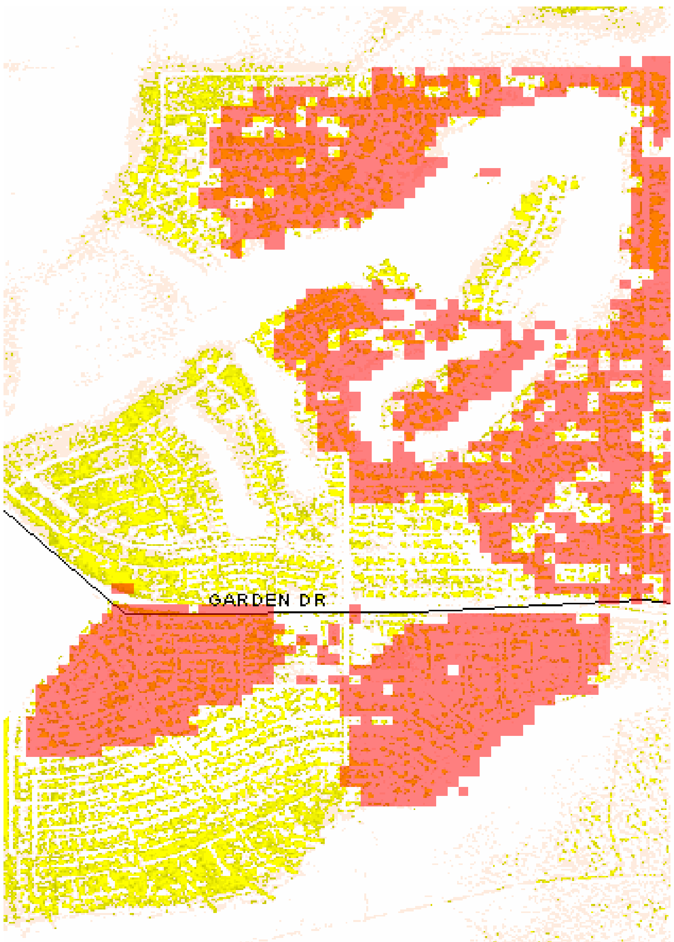

Figure 3. 1992 development data in semi-transparent red; 2001 development in yellows; only the "yellow" area of the red will be counted; Light pink is rejected urban (usually barren areas).

Make a grid mask for most urban categories:

Begin Option 1: ESRI Image Analysis:

First, change the format of the file to a Grid:

On the Image Analysis toolbar, in the Layers: window, click the down arrow and choose Ikonos_class16.img, then for the Model Types: window, click the down arrow and choose the Ikonos option.

In the Image Analysis window, click the down arrow and choose Save As….

In the Save Ikonos_class16.img window, for the Look in: option, navigate to the Ikonos directory

For Save as type: choose the ESRI GRID and for the Name: enter I_Class16_g

Press the Save button.

Use ArcCatalog to place I_Class16_g in ArcMap.

End Option 1: ESRI Image Analysis:

End using the ESRI Image Analysis Start using the ESRI Spatial Analysis

Step 4.2 Next, reclass the categories to Urban and [NoData or Zero]

Under the Spatial Analysis toolbar, in the Layers: window, click the down arrow and choose I_Class16_g.

Under the Spatial Analysis toolbar, click the down arrow and choose Reclassify.

On the Reclassify window

For Input raster enter the I_Class16_g (or if the grid was generated by ERDAS Imagine i_2class16_c1) file name.

For the Reclass Field, use the Class_names field.

Depending on the software you will use, in the next step set all the values to reclassify to one of the following:

1. If you will submit the result to ERDAS set:
   non-urban categories to 0
   OR
   urban to 1
2. If you will submit the result to ArcGIS set:
   non-urban categories to NoData
   urban to 1

For Output raster: navigate to the installation Ikonos directory and name the new file I_Class_urb_g.

Save as Type: ESRI GRID, press Save

Press the OK button. When complete the I_Class_urb_g file will appear on the ArcMap TOC. You may wish to change the Symbology to show that it is Classified with a Classification of only 1 Class of value 1.

Often, particularly in arid areas, the classification for barren soils and urban will be the same. You need to distinguish between the two. Experiment has shown that the imagery does not do this well. So make the following assumption about development and then carry out its implementation for the analysis: All building development will occur within about 150 meters of a road because of a need for transportation and utility access. To accomplish this, adopt the “roads” file from the GDT Dynamap/2000 Street Network data from July 2003 (hereafter referred to as the Census data) as standard. Though the date of the Street Network file from Dynamap will not exactly be the same date as the imagery, it will be within a few years of that date. Assume few major new roads are built between the imagery date and the Census roads date.

Step 4.3 Clip the preliminary urban category file by the roads buffer.
Now use the roads buffer completed at the end of Step 2. As mentioned there, if the locations are largely desert or barren, using all roads may include too much area. Consider using only those road files that area major or named roads. (i.e., in the attribute table for STATEABBREVIATIONcountynameS, sort by Road Name. Then delete all roads without a name). This will eliminate dirt trails in many locations that are unsuitable for development.

Make the preliminary urban category file, I_Class_urb_g

Under the Spatial Analyst toolbar, click the down arrow and choose Options

On the General tab, set Analysis mask to rds_clip_5mile_buf_150mbuf

On the Extent tab, set Snap Extent to: I_Class_urb_g

On the Cell Size tab, set Analysis cell size to Same as Layer “I_Class_urb_g”. Click OK.

Under the Spatial Analyst toolbar, click the down arrow and choose Raster Calculator

In the Raster Calculator window, double click on I_Class_urb_g so that it appears in the Calculator window. Press the Evaluate button.

The result should appear on the map and in the TOC as Calculation. Right click on Calculation and choose the Make Permanent option. In this window navigate to the Ikonos directory and save the file as i_clas_urbufg and for Save as

type: choose ESRI GRID. Click the Save button*. In the TOC slowly double click on the name Calculation and rename it i_clas_urbufg.

Let the unsupervised classifier reclassify only those areas in the preliminary-urban mask.

End using the ESRI Spatial Analysis, Start using the ESRI Image Analysis.

Step 4.4a On the Image Analysis toolbar, in the Layers: window, click the down arrow and again choose Ikonos_stud_area.img, then for the Model Types: window, click the down arrow and choose the IKONOS option.

Under the Image Analysis toolbar, click the down arrow and choose Options

On the General tab, set Analysis mask to i_clas_urbufg

On the Extent tab, set Analysis Extent to Ikonos_stud_area.img

On the Cell Size tab, set Analysis cell size to Same as Layer Ikonos_stud_area.img

On the Preferences tab, set the Resample Using: to Nearest Neighbor.

Click OK to submit these to the system.

In the Image Analysis window, click the down arrow and choose Classification, then the Unsupervised Classification option.

In the Unsupervised Classification window

For the Input Image: click the down arrow and choose the Ikonos_Buf15.img layer.

For Desired Number of Classes: fill in the value 16 (initially).

For the Output Image, navigate to the Ikonos directory and name the new image: i_2class16_g. Save as type will be ESRI GRID. Press the Save button.

Press the OK button.

<u>End Option 1: ESRI Image Analyst</u>:

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

Begin Option 2: ERDAS Imagine8.6:

Step 4.4b

Import the urban road buffer into an .Img format.

On the ERDAS Imagine8.6 main tool bar click on the Import button. In the Import/Export window change Type: to Grid and Media: to File. Navigate to the Ikonos directory and select i_clas_urbufg. For the Output File enter i_clas_urbuf_img. Click OK. In the Import GRID window, click OK.

Mask the 5-mile buffer image by the preliminary urban road buffer file.

On the ERDAS Imagine8.6 main tool bar click on Image Interpreter:, then select Utilities then Mask. In the Mask window:

For the Input File: navigate to the installation Ikonos directory and select Ikonos_Buf15_img.

For the Input Mask File: navigate to the installation Ikonos directory and select i_clas_urbuf_img.img. Check the attributes are set correctly by clicking on the Setup Recode… button.

In the Thematic Recode window, there should be two lines where the Value 0 represents areas to be dropped out of consideration and the Value 1 represents those to be retained. If this looks ok, click the OK button.

For the Output File: navigate to the installation Ikonos directory and enter I_class_urbuf_masked.img (Figure 4). Put a checkmark in the Ignore Zero in Output Stats box. Press OK to launch the process.

Figure 4. Ikonos Image masked (black) beyond 150-meter road buffer, ready for second unsupervised classification.

Run the second Unsupervised classification on only the likely urban areas.

On the main tool bar click the Classifier button. On the Classification menu, choose Unsupervised Classification.

In the Unsupervised Classification (Isodata) window for the Input Raster File navigate to your installation Ikonos directory and choose I_class_urbuf_masked.img. For the Output Cluster Layer, navigate to the installation Ikonos directory and for Files of type: enter GRID Stack (*.stk) then for File name: enter i_2class16_g. Uncheck the Output Signature Set box. For Number of Classes: enter 16.

Take the defaults for the rest of the options:

Initialize from Statistics

Maximum Iterations: 6

Convergence Threshold: 0.950

Skip Factors: x=1, y=1

Press OK to run the classification.

Warning boxes may appear. Just click OK so the processing can continue.
You will be informed when the processing is finished.

<u>End Option 2: ERDAS Imagine 8.6:</u>

Examine **i_2class16_g** (or **i_2class16_c1** if generated by ERDAS Imagine) closely. You should see output for only those areas that were previously designated as roughly urban. In the **i_2class16_g** (or **i_2class16_c1** if generated by ERDAS Imagine) determine which classifications best coordinate with real urban areas and still pick up as little barren land as possible. Normally the "lighter" or higher number categories are the most truly urban, while the "darker" areas in this classified image tend to be the barren areas. As a rule of thumb the lighter few categories will best represent true urban. It is recognized that some barren areas will still be included in this delineation of urban, but the technique should divide the two categories well.

As a point of interest, it was found empirically that better delineation of urban areas was accomplished by using a two-step unsupervised classification (with 16 categories) rather than a single step unsupervised classification with more categories (e.g., 32).

Step 4.5 Turn the classes determined to be urban into a grid that will also act as a mask:

End using the *Image* Analysis, Start using the *Spatial* Analysis

Reclass the categories to Urban and NoData:

Under the Spatial Analysis toolbar, in the Layers: window, click the down arrow and choose i_2class16_g (or i_2class16_c1 if generated by ERDAS Imagine).

Under the Spatial Analysis toolbar, click the down arrow and choose Options
- On the General tab, set Analysis mask to <None>. On the Extent tab, set Analysis Extent to StudyArea and Snap Extent to: <None>.
- On the Cell Size tab, set Analysis cell size to Same as Layer "i_2class16_g" (or "i_2class16_c1" if generated by ERDAS Imagine)
- Click OK to submit these to the system

Under the Spatial Analysis toolbar, click the down arrow and choose Reclassify
- On the Reclassify window
  - For Input raster choose i_2class16_g (or i_2class16_c1 if generated by ERDAS Imagine) for the file name.
  - For the Reclass Field, use the Class_names field.
  - For the Set values to reclassify section, set all the New values that are:
    - urban to 2
    - on each non-urban category, right click and chose the Remove Entries option.
  - Check Mark the statement Change missing values to NoData
  - For Output raster: navigate to the installation Ikonos directory and name the new file I_2_urb_g.
  - Save as Type: ESRI GRID, press Save
  - Press the OK button.
  - When complete, the I_2_urb_g file will appear on the ArcMap TOC. You may wish to change the Symbology to show that it is classified with a Classification of only one Class of value 2.

You need to take steps to begin to mitigate the difference in resolutions. The Ikonos imagery 5-meter resolution is 0.000040003 degrees. You have now identified urban at 5-meter resolution, but to compare it with the 30-meter NLCD, you need to "spread" the identification out to be more comparable, particularly since there are likely to be registration issues between some of the layers you are using. Further, you need to ensure that the urban determination is correctly preserved later when you deal with the NLCD at 30 meters. Therefore, buffer the individual sites to 20

meters. This process therefore includes the yards around a building, which, of course, anyone would consider part of the urban landscape.

Under the Spatial Analyst toolbar, click the down arrow and choose Options.
- On the General tab, set Analysis mask to None
- On the Extent tab, set Analysis Extent to i_2_urb_g
- On the Cell Size tab, set Analysis cell size to Same as Layer "Ikonos_stud_area.img" (The Ikonos imagery 5-meter resolution is 0.000040003 degrees.)

Under the Spatial Analysis toolbar, click the down arrow and choose Distance… then Straight Line
- In the Straight Line evaluation box, enter
    - For Distance to: enter: i_2_urb_g
    - For Maximum Distance: enter: 0.00016 (degrees - that's 4 times 5 meters or 20 meters).
    - For Output cell size: enter: 0.00004
    - Do not Create direction or Create allocation
    - For Output raster navigate to the Ikonos directory and enter i_2urbbbuf_g
    - Press OK
- This will generate a file with more area extent to it than that obtained from the original image (Figure 5).

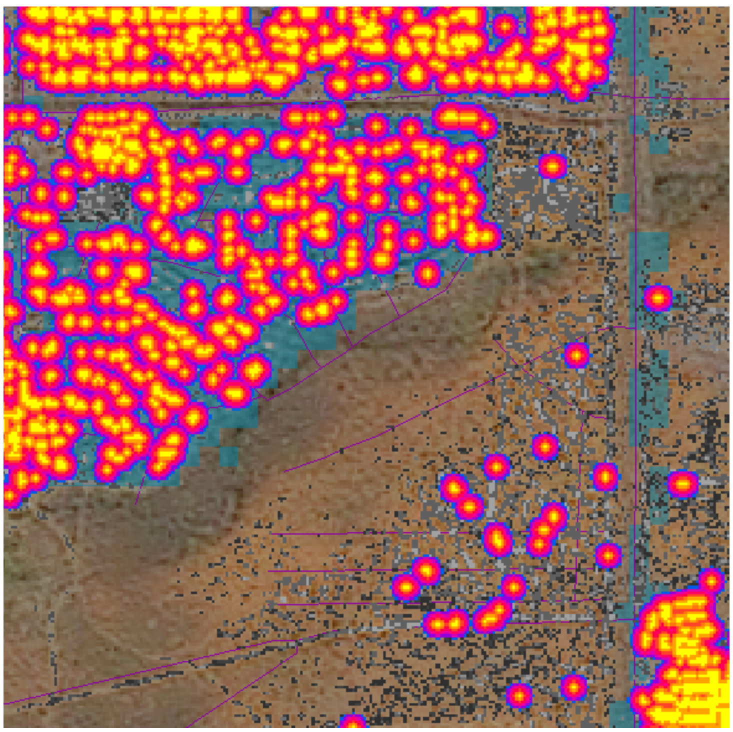

Figure 5. Expanding the urban locations (yellow) to a parcel size extent (orange balls). Noise removed is spectecled grays. Transparent blue squares along the road show incorrectly identified urban in the 1992 USGS NLCD.

Now you need to simplify the i_2urbbbuf_g layer to a single value.

Under the Spatial Analysis toolbar, click the down arrow and choose Raster Calculator.

On the Raster Calculator window enter a statement of the form (if values in this layer are greater than or equal to zero, assign value 2, otherwise assign a zero): Con ([i_2urbbbuf_g] >= 0, 2, 0).

Click the Evaluate button.

When complete, Calculation file will appear on the ArcMap TOC with a single value of 2. Right click on Calculation and choose the Make Permanent option. In this window navigate to the Ikonos directory and save the file as i_2_urb4_g and for Save as type: choose ESRI GRID. Click the Save button.*

Still Too Much Noise Remains?

Occasionally by this point some i_2_urb4_g files will still have too much land mistakenly identified as urban. The most common incorrect situations are barren areas and mountains in arid areas, agricultural fields in the South, or snow on the ground in the North. This is particularly irritating in areas that are sparely developed. If the procedure has resulted for these reasons in an unacceptable rating in the next step, define obvious urban/develop areas using polygons and cut away most of the noise outside of these polygons. To accomplish this, a brief outline follows. You will have to modify it based on your particular situation.

Define Polygon Shape: In ArcCatalog, click on the installation directory name, go to file on the menu bar, and choose New then Shapefile… In the Create New Shapefile window Name the file Masker. The Feature Type: is Polygon. For the Spatial Reference, press the Edit… button and Import. Pick one of the existing files in the standard Geographic WGS84 projections and Add it to the Masker file. Put this empty file in the ArcMap window.

Make MASKER Polygon Shape: In the ArcMap window, click on the Editor Toolbar, then click Start Editing. On the Start Editing window, choose the directory that lists MASKER. Make sure that the Target window lists Masker. The Task window should read Create New Feature. Click on the Sketch Tool icon. Use this tool to define those areas that you want to SAVE after you use Masker

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

to eliminate the noisy areas. Save your edits once in a while, then press Stop Editing when you are finished.

Guidance: You will make Masker as a definition of areas you want to save. To see the general areas, in the ArcMap window display both the Urban areas file and the cities_dtl file. You will certainly want to define these as polygons as well as other obvious areas. Remember, the polygons are those areas you wish to KEEP.

Make Mask: When you are done with Masker, you need to change it to a GRID format. Under Spatial Analyst click on Convert, then on Features to Raster… Fill in the requested items in the window, name the output grid MaskerG. It will appear in the TOC when done.

Clip out unwanted areas: Under the Spatial Analyst toolbar, click the down arrow and choose Options

On the General tab, set Analysis mask to MaskerG.
On the Extent tab, set Analysis Extent to StudyArea.
On the Cell Size tab, set Analysis cell size to Same as Layer "i_2_urb4_g".

Under the Spatial Analyst toolbar, click the down arrow and choose Raster Calculator.

In the Raster Calculator window, double click on Layer i_2_urb4_g so that it appears in the Calculator window. Press the Evaluate button.

The result should appear on the map and in the TOC as Calculation. Right click on Calculation and choose the Make Permanent option. In this window navigate to the Ikonos directory and save the file as i_2_urb4_g_m and for Save as type: choose ESRI GRID. In the TOC rename it to i_2_urb4_g_m.*

Step 4.6 Do a Quality Control evaluation on the urban-class layer per criteria per Preliminary Quality Evaluation

Although you have not completed all tasks, at this point you are probably pretty familiar with the issues for the installation. Copy out and then fill out the Prelimi-

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

nary Quality Evaluation form below for this Step 4. Save it as a Word .doc in the installation directory.

Preliminary Quality Evaluation For ***Installation Name***

Do an inspection of the result Ikonos image urban identification and in terms of that resultant image, and answer the following questions:

1. How well does the Ikonos classification of urban correspond to what one would think of as urban from comparison with the original study area image?

   1 2 3 4 5 Best

2. Roughly by how many percent would you think, the urban areas are:

   Overestimated 1 3 5 10 20 percent

   Underestimated 1 3 5 10 20 percent

3. Identify the location within the study area that is the least accurate. What appears to be the cause? What would eliminate the problem? (Example pictures of the points you make are desired).

4. Is the result of this analysis

   Good OK Fair Poor Unacceptable

   If unacceptable, what needs to be done to make it acceptable?

If in point 2, the over or under estimate was more than 20 percent, redo Steps 4.1 and 4.4 using 24-100 classes rather than 16.

Step 5: Generate land cover from the NLCD

Step 5 General description: Land use changes will be determined by comparing the National Land Cover Data – NLCD. Download the NLCD; import it to your format by reprojecting it and clipping it to the study area extent and at the resolution of the NLCD. Then make a mask that excludes areas that cannot be developed.

A few installations are in locations not covered by the NLCD. For these few, an alternative approach was generated such that similar final encroachment indices (as described in Step 6) could be generated. This alternative procedure is described in Appendix A.

Step 5.1 Obtain the NLCD for the state you are working in.
This can be had from the web for all states. If you need more than one state to cover the study area and buffer, do each state separately to Clip NLCD Grid to the Study Area. In this step you will sew the states together.

To retrieve the data from its web home, go to the following web location:
http://edcftp.cr.usgs.gov/pub/data/landcover/states

Right click on the GeoTiff formatted state file you want (it has the .tif.gz extension) and then save target as..... You might wish to save this in a directory dedicated to manipulating NLCD data. Be sure the .gz extension is part of the downloaded file name (*.bin.gz). Lastly, be sure to save the associated txt files into the same directory, particularly the state_readme.txt and the state_FGDC.txt files. [FGDC is the United States Federal Geographic Data Committee. It has the lead role in defining spatial metadata standards.]

Go to the directory where you have saved the compressed NLCD file and double click on the name. If you have associated the .gz extension with WinZip, this action should bring up the WinZip utility. Extract to your NLCD directory. Close WinZip.

In ArcCatalog look at the file. ArcCatalog probably recognizes the file and recognizes that the projection is probably the wrong projection (see example projection information box). Therefore you must do a reprojection.

```
Projection: Albers Conical Equal Area
  Datum: NAD83
  Spheroid: GRS80
  Standard Parallels: 29.5 degrees North Latitude
                      45.5 degrees North Latitude
  Central Meridian:  96 degrees  West Longitude
  Origin of the Projection: 23 degrees North Latitude
      False Easting:   0 meters
      False Northing:  0 meters
Number of Lines (rows/height): 23328
Number of Samples (columns/width): 20036
Number of Bands: 1   Pixel size: 30 X 30 meters
Projection Coordinates (center of pixel, projection meters)
     Upper Left Corner:  -1747230 meters(X),
                          1701780 meters(Y)
     Lower Right Corner: -1146180 meters(X),
                          1001970 meters(Y)
```

Step 5.2 Import to TIFF Format

Do the following steps in ERDAS Imagine

Start using the ERDAS Imagine Version 8.6

Open Imagine

Click on the Import button

In the Import/Export window Type is GeoTIFF, Media is File. Browse to find the Input File for your state in the NLCD directory.

Name the Output File (make sure you are putting it in the desired NLCD directory) StateName_projection (e.g., Virginia_albers). Note: the projection is stated in the .txt file that came in the .zip package. For the Files of type: box select Img (the default). Press the OK button.

The Import TIFF box should appear with the correct data. Check that the rows and columns are correct. Press the OK button several times to get it started.

Step 5.3 Reproject Images

When the data is available, to reproject, click on the Data Prep button on the main menu bar. In the Data Preparation box, click on the Reproject Images button. In the Reproject Images box, chose the state_projection.img file name. For the output file:

Name it State_ll and put it in the NLCD directory (remember the name must be less than 13 characters).

For the Files of type: select GRID Stack (*.stk). Press OK.

In the Output Projection Section change the characteristics of the projection you are using to Geographic and Lat/Lon (WGS 84). Take the defaults for other options. (Note: sometimes an error message appears. Just click OK to the message and let the processing finish.)

End using the ***ERDAS Imagine***, start using the ***ESRI ArcGIS***

When the reprojection is finished, two GRIDS will be listed. Either can be used. We will use the layer that ends in “c1”. Use ArcCatalog Metadata to make sure the projection is correct. Then submit it to ArcMap. Check to make sure that there is a sense that features between layers are consistent.

Step 5.4 Clip NLCD Grid to the Study Area

Use the grid of the study area to clip out the NLCD portion you are interested in.

Start using the Spatial Analysis.

Under the Spatial Analyst toolbar, click the down arrow and choose Options.

On the General tab, set Analysis mask to StudyArea.

On the Extent tab, set Analysis Extent to StudyArea and Snap Extent to: state_nlcc1.

On the Cell Size tab, set Analysis cell size to Same as Layer “state_nlcc1”.

Under the Spatial Analyst toolbar, click the down arrow and choose Raster Calculator.

In the Raster Calculator window, double click on Layer state_nlcc1 so that it appears in the Calculator window. Press the Evaluate button.

The result should appear on the map and in the TOC as Calculation. Right click on Calculation and choose the Make Permanent option. In this window navigate to the NLCD directory and save the file as NLCD_StudArea and for Save as type: choose ESRI GRID.* In the TOC slowly double click on the name Calculation and rename it NLCD_StudArea. Right click on the state_nlcc1 and click the Remove button.

If your study area includes more than one state:

In this step you will sew the states together. Since each state includes a small buffer of land use of the adjacent state, you need to put these together without double counting the overlaps.

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

Under the Spatial Analyst toolbar, click the down arrow and choose Options.

On the General tab, set Analysis mask to StudyArea.

On the Extent tab, set Analysis Extent to StudyArea.

On the Cell Size tab, set Analysis cell size to Same as Layer "state_nlcc1".

Under the Spatial Analyst toolbar, click the down arrow and choose Raster Calculator.

In the Raster Calculator window set up a conditional statement similar to:

Con ([nlcd_studarState1] > 0, [nlcd_studarState1], [nlcd_studaraStat2])

Press the Evaluate button.

The result should appear on the map and in the TOC as Calculation.

Right click on Calculation and choose the Make Permanent option. In this window navigate to the NLCD directory and save the file as NLCD_StudArea and for Save as type: choose ESRI GRID. In the TOC slowly double click on the name Calculation and rename it NLCD_StudArea.* Right click on the state_nlcc1 and click the Remove button.

Step 5.5 Reclass the NLCD data into an urban category layer

From the NLCD data reclass the data from categories 21, 22 and 23 into an urban category layer.

Under the Spatial Analyst toolbar, click the down arrow and choose Reclassify. In the Reclassify window:

Choose NLCD_StudArea as the Input Raster, Value as the Reclass Field and at the bottom of the box, name the Output raster NLCD_urban of Type: ESRI GRID inside the NLCD directory.

In the Set values to reclassify section, for:

Categories 21, 22, 23 set New values to 1

All other categories, set New values to 0.

Click OK. NLCD_urban grid file will appear in the ArcMap window. This is the extent of urban land in about 1992.

Step 5.6 Generate an exclude mask from the NLCD for areas that will never be developed land.

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

From the NLCD you can determine that there are areas that will never be developed land. Now generate a mask to exclude these areas in the later analyses:

11 Open Water
12 Perennial Ice/Snow
31 Bare Rock/Sand/Clay
32 Quarries/Strip Mines/Gravel Pits

Under the Spatial Analyst toolbar, click the down arrow and choose Reclassify. In the Reclassify window:

Choose NLCD_StudArea as the Input Raster, Value as the Reclass Field and at the bottom of the box, name the Output raster NLCD_exclude of Type: ESRI GRID inside the NLCD directory.

In the Set values to reclassify section, for:

Categories 11, 12, 31, and 32 set New values to 1

All other categories, set New values to 0.

Click OK. NLCD_exclude grid file will appear in the ArcMap window.

Step 6: Generate trend tabular data

Step 6 General description: At this point you have two data sets that can be overlaid visually (such as in Figure 3) to illustrate changes in urbanization over time. Now you need to compare these quantitatively. Do this by spatially linking the Ikonos urban data layer table with the NLCD urban areas. Then delineate which buffer the urban areas are in. Finally, generate a table showing the growth during the period and use this to do trend predictions to the year 2020. In this manner, you will have a simple summary evaluation of the state of encroachment current and in the future.

Step 6.1 Make a combined grid file of 1992 and 2001 urban:

Start using the ***ArcToolbox***
Export from Raster; use the Grid to Polygon Coverage tool. Input grid is nlcd_exclude, create output coverage called Exclude. Leave Weed Tolerance alone.

Start using ***ArcMap***
Add Exclude coverage to your map. Change Symbology to show the categories unique values. Change the value field to GRID_CODE. Press the Add All Values button and uncheck the box All other values. Click Apply and OK.

Right click Exclude coverage layer and then Open Attributes Table. Sort GRID_CODE Ascending and select all of the Zero value records. Export those records to a new coverage file and call it Exclude_Mask. Add it to the map. You can now delete the Exclude coverage if you want.

Start using the ***Spatial*** **Analysis**
Exclude never to be developed land:

- Under the Spatial Analyst toolbar, click the down arrow and choose Options
  - On the General tab, set Analysis mask to Exclude_Mask
  - On the Extent tab, set Analysis Extent to Exclude_Mask
  - On the Cell Size tab, set Analysis cell size to 0.00004 (the Ikonos imagery 5-meter resolution)
- Under the Spatial Analysis toolbar, click the down arrow and choose Raster Calculator
  - In the Raster Calculator evaluation box, click on the last urban data file so the window reads:
    [i_2_urb4_g]
    or
    [i_2_urb4_g_m] if you had to use a mask made from polygons.
  - Click the Evaluate button.
  - This will result in the same file but with non-buildable areas excluded.

The result should appear on the map and in the TOC as Calculation. Right click on Calculation and choose the Make Permanent option. In this window navigate to the Ikonos directory. For Save as type: choose ESRI GRID and save the file as i_2_urb4xg. Click the Save button.*

Under the Spatial Analyst toolbar, click the down arrow and choose Options

On the General tab, set Analysis mask to i_2_urb4xg

On the Extent tab, set Analysis Extent to i_2_urb4xg

On the Cell Size tab, set Analysis cell size to 0.00010 (this is one of the steps in which you begin to mitigate the difference in resolutions. The Ikonos imagery 5-meter resolution is 0.00004 degrees. Decrease this by 2.5 times to about 12.5 meters. This will also allow for faster calculation time in the next several steps).

Under the *Spatial* Analysis toolbar, click the down arrow and choose Raster Calculator.

In the Raster Calculator evaluation box, enter a statement similar to:

Con ([NLCD_urban] == 1, 1, 2)

This will assign values of 1 to cells that were urban in 1992 and 2001 and values of 2 to cell that were urban only in 2001.

Click the Evaluate button.

The result should appear on the map and in the TOC as Calculation. Right click on Calculation and choose the Make Permanent option. In this window navigate to the installation directory. For Save as type: choose ESRI GRID and name the file urb92_01g. Click the Save button.†

In the TOC slowly double click on the name Calculation and rename it urb92_01g.

Step 6.2 Calculate unique values for different urban growth degrees at different times depending on the buffer.

Now you need to apply an equation that integrates the characteristics of the buffers and the different urban growth degrees at different times. The resulting values are unique, depending on the buffer in which they occur.

Under the Spatial Analyst toolbar, click the down arrow and choose Options.

On the General tab, set Analysis mask to <None>

On the Extent tab, set Analysis Extent to Same as Layer “BUF15_G”

---

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

† You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

On the Cell Size tab, set Analysis cell size to 0.00010 (our standard from now on).

Under the *Spatial* Analysis toolbar, click the down arrow and choose Raster Calculator.

In the Raster Calculator evaluation box, enter the a statement similar to:
Con ([Buf15_G] == 1, [urb92_01g], [urb92_01g] + 5)

This will assign values of:

1 to cells that were urban in 1992 and 2001 and are within a 1-mile buffer of the installation.

2 to cells that were urban only in 2001 (i.e. newly developed) and are within a 1-mile buffer of the installation.

6 to cells that were urban in 1992 and 2001 and are within a 1- to 5-mile buffer of the installation.

7 to cells that were urban only in 2001 (i.e. newly developed) and are within a 1- to 5-mile buffer of the installation.

Click the Evaluate button.

The result should appear on the map and in the TOC as Calculation. Right click on Calculation and choose the Make Permanent option*. In this window, navigate to the installation directory and save the file as urbbuf_92_01g and for Save as type: choose ESRI GRID. Click the Save button.

In the TOC slowly double click on the name Calculation and rename it urbbuf_92_01g. urbbuf_92_01g is the product of this effort and will be sent to the TABS office. From it, you will generate the growth rates and trend data.

Step 6.3 Export the data to an Excel file

You now have the data needed to make the comparisons among the installations.

Right click on the urbbuf_92_01g file in the TOC and click on Open Attribute Table. Accompanying this Protocol, you will find a prepared MS Excel table, Example_Installationname_urbbuf_92_01.xls. This file has all the calculation routines already integrated into it, so your job is finding and plugging in values from your installation. Copy Example_Installationname_urbbuf_92_01.xls to your installation directory. Rename it to your installation name. Open the file. Copy the values from the urbbuf_92_01g file Attribute Table to the similar locations in the .xls file. You will need only to enter values in those colored boxes (colored Red below and YELLOW in the Excel spread sheet).

---

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

Step 6.4 Populate the table and generate the trend data in MS Excel.

Start using *MS Excel*

Generate Trend data in MS Excel.

You will see that the Attribute Table only has a "Count" column, rather than acres. Count is adequate because we will deal only with percentages, not absolute areas. This makes comparisons between installations more reasonable.

Under the Legend column enter the correct label for each value:

Legend	Value
1992 – 0- to 1-mile buffer	1
2001 – 0-to 1-mile buffer	2
1992 - 2- to 5-mile buffer	6
2001 - 2- to 5-mile buffer	7

Now, you need to know the amount of area within each buffer. Go to ArcMap and right click on the BUF15_G file in the TOC. Move down the menu and choose Open Attribute Table.

In the attribute table there are only Count values for the 0- to1-mile and the 1- to 5-mile buffers (MAKE SURE that the resolution used in both BUF15_G and urbbuf_92_01g are the same, otherwise the cell counts will not be comparable). From the Attributes of BUF15_G for the inner buffer (value 1) copy the Count to the new Column BufferCount in the Excel file for Values 1 and 2 (the 0- to 1-mile buffer values) and from the Attributes of BUF15_G for the outer buffer (value 2) copy the Count to the Column (BufferCount) in the Excel file for Values 6 and 7 (the 1- to 5-mile buffer values).

From this table generate the rate of growth in percentage between NLCD (1992) and Ikonos image (for short hand, use 2001). Use these values to generate a projection to the year 2020. Additional inputs required are:

Year of Image

The NLCDs are all assumed to be 1992. The year of the Ikonos image is not available for files that had a 5-meter resolution. They are all assumed to be 2003. For any received 1-meter data that was translated to 5-meter, the .txt files that came with the 1-meter data will have the image date. Find it and enter it in the "2003" rows.

Quality Evaluation

In the Quality Evaluation you gave a numerical rating (1-5 with 5 as best) in answer to the first question. Enter this value once in this column.

OverUnder%

When you completed your Preliminary Quality Evaluation you made an estimate of how well the imagery evaluation worked. Take the Overestimated%, subtract the Underestimated%, and enter this value in the table. For example enter .1 for 10%. Negative values indicate a net underestimate. Most values are expected to be positive.

Count of Undevelopable land 1992. If land is undevelopable, it will help protect the installation against encroachment. This value is available from the attribute file of the NLCD_Exclude. Do the evaluation for the different buffers to see how well protected the installation is.

Generate the basic excluded data for the 0- to 1-mile buffer:

Under the Spatial Analyst toolbar, click the down arrow and choose Options.

On the General tab, set the Working directory to the installation NLCD directory and set Analysis mask to Bond_Buf15 (or Bond_Buf15_trunc if this is what you used).

On the Extent tab, set Analysis Extent to Same as Layer "NLCD_StudArea"

On the Cell Size tab, set Analysis cell size to Same as Layer "NLCD_StudArea"

Under the *Spatial* Analysis toolbar, click the down arrow and choose Raster Calculator

In the Raster Calculator evaluation box, enter the a statement similar to the following two line expression:

```
con([nlcd_exclude] == 1  & [buf15_g] == 1,1,~
con([buf15_g] == 1,0))
```

This statement will pull out only those cells within the 1-mile buffer. Remember that if the study area was truncated, you must substitute the buf15_g_trunc or equivalent file.

The new Calculation file will appear on the TOC.

Right click on Calculation and choose the Make Permanent option. In this window navigate to the NLCD directory and save the file as xCount1. For Save as type: choose ESRI GRID. Click the Save button*. In the TOC slowly double click on the name Calculation and rename it xCount1.

---

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

Right click on xCount1, click on Open Attribute Table. Fill in the following information in the excel table.

Count of Undevelopable Land

% Undevelopable land is the Count of Undevelopable Land cells divided by the total count of cells in the xCount1 attribute table. To get the Total Count, right click on the Count column, select "statistics" and enter the value for Sum: into the spreadsheet under the Total Cells in buffer column.

After closing the statistics dialog box, copy the number in the Count column that corresponds to objectID 1 in the xCount1 attribute table. This is the number of cells that cannot be developed within the 1-mile buffer. Paste this figure into the Excel spreadsheet under the "Count of undevelopable land cells" column for the 1-mile buffer.

Generate the basic excluded data for the 1- to 5-mile buffer:

Under the Spatial Analyst toolbar, click the down arrow and choose Options.

On the General tab, set the Working directory to the installation NLCD directory and set Analysis mask to Bond_Buf15
(or Bond_Buf15_trunc)

On the Extent tab, set Analysis Extent to Same as Layer "NLCD_StudArea"

On the Cell Size tab, set Analysis cell size to Same as Layer "NLCD_StudArea"

Under the *Spatial* Analysis toolbar, click the down arrow and choose Raster Calculator.

In the Raster Calculator evaluation box, enter the a statement similar to the following two-line expression:

con([nlcd_exclude] == 1 & [buf15_g] == 2,1,~
con([buf15_g] == 2,0))

This statement will pull out only those cells within the 1- to 5-mile buffer. Remember that if the study area was truncated you must substitute the buf15_g_trunc or equivalent file.

The new Calculation file will appear on the TOC.

Right click on Calculation and choose the Make Permanent option. In this window, navigate to the NLCD directory and save the file as xCount5. For

Save as type: choose ESRI GRID. Click the Save button.* In the TOC slowly double click on the name Calculation and rename it xCount5. Right click on xCount5, click on Open Attribute Table. Fill in the following information in the excel table.

Count of Undevelopable Land

% Undevelopable land is the Count of Undevelopable Land cells divided by the total count of cells in the xCount5 attribute table. To get the Total Cells in the 5-mile buffer, right click on the Count column, select "statistics" and enter the value for Sum: into the spreadsheet under the Total Cells in buffer column.

After closing the statistics dialog box, copy the number in the Count column that corresponds to objectID 1 in the xCount5 attribute table. This is the number of cells that cannot be developed within the 5-mile buffer. Paste this figure into the Excel spreadsheet under the "Count of undevelopable land cells" column for the 5-mile buffer.

The ratio of these two values, suggests how well the nearby areas are naturally protected from development. Ratios greater than 1 suggest that the installation is more protected.

New corrected value for Count of Undevelopable land cells

Because the excluded cells in the xCount files were generated from the NLCD data, the cell counts are not directly comparable to the cell counts in the Buf15_g files due to the differences in resolution. The Excel spreadsheet has a built-in conversion equation to compensate for this discrepancy and will correct for these differences in resolution. This correction is displayed in the "new corrected value for Count of undevelopable land cells" column of the spreadsheet.

Urban %

Count/BufferCount in each row is derived by the formula; it uses the OverUnder% to correct for evaluated inaccuracies.

Total Urban %

Sum of Urban within Buffer so there is a value only every other row.

Straight-line % Increase/Year

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

Urban % for the 1-mile buffer divided by the number of years between NLCD and Ikonos Image. Since the NLCD is made up of many TM images, it is assumed to be roughly 1992. The Ikonos images vary by a few years. Check the metadata file for the correct date.

Straight-line Trend to 2020 %Urban (Developable)

Beginning Total Urban % Developable plus the product of % increase/year times the number of years from the Ikonos image to 2020.

Monomolecular Trend to 2020 %Urban

Most development will start slowly and have a high rate in the mid portions of its development cycle. The rate will decrease as the best lands have already been used to a point where it will take a long time to use those last less choice parcels. The Monomolecular trend takes this into account. It will also avoid the situation where the Straight-line will easily go beyond 100%. The Monomolecular Trend uses the same information, but is a hyperbolic curve tending to a 100% asymptote, and results stay within the 100% range.

During the development of the data researchers came across or generated several pieces of data that are useful in evaluating encroachment risks. In this section you will gather these into the same .xls table. These will be used to generate comparison tables among the installations in the final group report to the TABS office. The purpose of each, data source location, and/or formula are discussed below:

UrbanizationRate/Cell 1mile. You need to normalize the rates in the buffers above to a cross-installations rate. This value is calculated as %Increase/Year divided by the 1 mile BufferCount.

UrbanizationRate/Cell 2_5miles. [Note: this is the 1- to 5-mile buffer.] This value is calculated as %Increase/Year divided by the 5-mile BufferCount.

1mile vs. 5mile buffer Increase/Year ratio. Divide the UrbanizationRate/Cell 1mile by the UrbanizationRate/Cell 2_5miles. [Note: this is the 1- to 5-mile buffer.] A ratio greater than 1 indicates urbanization is occurring at a greater rate near the installation – this is less desirable than a value less than 1, which indicates encroachment is tending to stay away from the installation.

Length of installation perimeter. The greater the length of the edge of an installation, the greater the potential of encroachment. Read this value from the attribute table of the vector file: Boundary as follows:

On the TOC right click on Boundary, click on Open Attribute Table. Find the column Perimeter. Enter the value of Perimeter as the Length of installation perimeter.

Perimeter/area index. The greater the boundary varies from a circle; the greater is the opportunity for the perimeter to be encroached upon. To generate this value divide Boundary by Area value.

On the TOC right click on Boundary, click on Open Attribute Table. Find the column Area. Divide the Perimeter by the Area to get the Perimeter/area index.

1992 Urban Land Use Counts: The issue here is what is the mix of land use types that can cause encroachment? It would be difficult and unreliable to pull this information from the Ikonos images, but it can be read directly from a layer you will create.

Generate the basic data for the entire 5-mile buffer:

Under the Spatial Analyst toolbar, click the down arrow and choose Options.

On the General tab, set the Working directory to the installation directory and set Analysis mask to Bond_Buf15

On the Extent tab, set Analysis Extent to Same as Layer "NLCD_StudArea"

On the Cell Size tab, set Analysis cell size to Same as Layer "NLCD_StudArea"

Under the *Spatial* Analysis toolbar, click the down arrow and choose Raster Calculator

In the Raster Calculator evaluation box, enter the a statement similar to:

con([nlcd_urban] == 1,[NLCD_StudArea],0)

This statement will pull out only those urban cells within the 5-mile buffer.

The new Calculation file will appear on the TOC.

Right click on Calculation and choose the Make Permanent option. In this window, navigate to the NLCD directory and save the file as UrbanCount5. For Save as type: choose ESRI GRID. Click the Save button*. In the TOC slowly double click on the name Calculation and rename it UrbanCount5. Right click on UrbanCount5, and then click on Open Attribute Table. Fill in the following information in the excel table.

5-mile 1992 Count. To find percentages you need to know the total area in the 5-mile buffer. From the UrbanCount5 file attribute table, right click

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

on the Count column and choose Statistics. In the Statistics of urban-count5 window, the Sum: is the number to add to the Excel table.

5-mile 1992 Count of Low Density Housing. This can be read directly from the UrbanCount5 file attribute table in the Count column for value 21.

5-mile 1992 Count of High Density Housing. This can be read directly from the UrbanCount5 file attribute table in the Count column for value 22.

5-mile 1992 Low to High Density Ratio. To characterize the growth demographics, generate this index by dividing the 1992 Count of Low Density Housing by the 1992 Count of High Density Housing.

5-mile 1992 Count of Commercial Transportation. This can be read directly from the UrbanCount5 file attribute table in the Count column for value 23.

Generate the basic data for the 1-mile buffer:

Under the Spatial Analyst toolbar, click the down arrow and choose Options

On the General tab, set the Working directory to the installation directory and set Analysis mask to Bond_Buf15

On the Extent tab, set Analysis Extent to Same as Layer "BUF15_G"

On the Cell Size tab, set Analysis cell size to Same as Layer "BUF15_G". Remember that if the study area was truncated you must substitute the buf15_g_trunc or equivalent file.

Under the *Spatial* Analysis toolbar, click the down arrow and choose Raster Calculator

In the Raster Calculator evaluation box, enter a statement similar to: con([BUF15_G] == 1,1)

This statement will create a 1-mile GRID buffer. Remember that if the study area was truncated you must substitute the buf15_g_trunc or equivalent file.

The new Calculation file will appear on the TOC.

Right click on Calculation and choose the Make Permanent option. In this window navigate to the NLCD directory and save the file as Buf1_G. For Save as type: choose ESRI GRID. Click the Save button.* In the TOC slowly double click on the name Calculation and rename it Buf1_G (or Buf1_G_trunc if appropriate).

On the General tab, set Analysis mask to Buf1_G or Buf1_G_trunc.

On the Extent tab, set Analysis Extent to Same as Layer "Buf1_G" or "Buf1_G_trunc"

On the Cell Size tab, set Analysis cell size to Same as Layer "NLCD_StudArea"

Under the *Spatial* Analysis toolbar, click the down arrow and choose Raster Calculator

In the Raster Calculator evaluation box, enter a statement similar to: con([Buf1_G] == 1,[UrbanCount5],0).

This statement will pull out only those urban cells within the 1-mile buffer. Remember that if you truncated the study area, you must substitute the buf1_g_trunc or equivalent file.

The new Calculation file will appear on the TOC.

Right click on Calculation and choose the Make Permanent option. In this window, navigate to the NLCD directory and save the file as UrbanCount1. For Save as type: choose ESRI GRID. Click the Save button†. In the TOC slowly double click on the name Calculation and rename it UrbanCount1.

Right click on UrbanCount1, click on Open Attribute Table. Fill in the following information in the excel table.

1-mile 1992 Count. To find percentages you need to know the total area in the 1-mile buffer. From the UrbanCount1 file attribute table, right click on the Count column and choose Statistics. In the Statistics of urbancount1 window, the Sum: is the number to add to the Excel table.

* You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes halt the ARCMap session.

† You may wish to use the work-around for saving calculations, as using the Make Permanent option will sometimes kill the ARCMap session.

1-mile 1992 Count of Low Density Housing. This can be read directly from the UrbanCount1 file attribute table in the Count column for value 21.

1-mile 1992 Count of High Density Housing. This can be read directly from the UrbanCount1 file attribute table in the Count column for value 22.

1-mile 1992 Low to High Density Ratio. To characterize the growth demographics we generate this index by dividing the 1-mile 1992 Count of Low Density Housing by the 1-mile 1992 Count of High Density Housing.

1-mile 1992 Count of Commercial Transportation. This can be read directly from the UrbanCount1 file attribute table in the Count column for value 23.

Ratio of low to High density compared between the 1- to 5-mile buffer and the 0- to 1-mile buffer. This ratio shows the character of the development near the installation. A value greater than 1 shows more low density near installation. The greater the value, the more predominant the low-density housing is near the installation.

Length of Roads within 5 miles. The presence of roads is a very important attractor for development. In fact, development rarely occurs unless road access already exists. To get this value, use rds_clip_5mile_buf as follows:

On the TOC right click on the file rds_clip_5mile_buf, click on Open Attribute Table. Right click on the column LENGTH. The Statistics of rds_clip_5mile_buf window will appear. Enter the value of SUM: as the Length of Roads within 5 miles.

Roads/unitarea within 5 miles. The formula already exists in the Excel sheet to divide the Length of Roads within 1- to 5-mile by the 1992 COUNT for the 5-mile buffer.

Length of Roads within 1 mile. To get this value, use rds_clip_5mile_buf as follows:

In the TOC, click on the Bond_Buf15 file (or Bond_Buf15_trunc file) to highlight it. Right click on the Bond_Buf15 file, click on Open Attribute Table. Select the row that corresponds to the 1-mile buffer. It will be highlighted on the map itself.

On the Main Menu, click Tools, then Geoprocessing Wizard.

Chose Clip one layer based on another, then Next>.

Select the input layer to clip: rds_clip_5mile_buf

Select a polygon clip layer: The Bond_Buf15 file (or Bond_Buf15_trunc file). MAKE SURE that the Use selected features only box has a checkmark in it.

Specify the output shapefile: roads1_clip in the installation directory.

Then click the Finish button.

The new roads1_clip file will appear on the TOC. Right click on roads1_clip, click on Open Attribute Table. Right click on the column LENGTH. Click on the Statistics option. The Statistics of roads1_clip box will appear. Enter the value of SUM: as the Length of Roads within 1 mile.

Roads/unitarea within 1 mile. In this step you determine the density of the road network. Simply divide the Length of Roads within 1 mile by the 1992 COUNT for the 1-mile buffer.

Ratio of Roads/unitarea within 1 mile divided by Roads/unitarea within 5 miles. A number less than 1 is good – it means that the intensity of road building near the installation is less than is characteristic of the nearby regions.

Towns within 5 miles & Town Population within 5 miles. The more towns that exist near the installation, the more attractiveness there exists for potential development to occur. To generate this value, clip the vector file cities_dtl with Bond_Buf15 (or Bond_Buf15_trunc file).

On the Main Menu, click Tools, then Geoprocessing Wizard.

Chose Clip one layer based on another, then Next>.

Select the input layer to clip: cities_dtl

Select a polygon clip layer: The Bond_Buf15 file (or Bond_Buf15_trunc file)

Specify the output shapefile: cities5_clip in the installation directory.

Then click the Finish button.

The new cities5_clip file will appear on the TOC. Right click on cities5_clip, click on Open Attribute Table and read the number of rows. This is the value of Towns within 5 miles. Right click on the column POP_98. Choose the Statistics option. The Statistics of cities5_clip will appear. Enter the value of SUM: as the Town Population within 5 miles.

Towns within 1 mile & Town Population within 1 mile. The more towns that exist near the installation, the more attractiveness there exists for potential development to occur. To generate this value, select the 1-mile buffer and clip the vector files, Bond_Buf15 (or Bond_Buf15_trunc file) with cities_dtl.

In the TOC, click on the Bond_Buf15 file (or Bond_Buf15_trunc file) to highlight it. Right click on the Bond_Buf15 file, click on Open Attribute Table. Select the row that corresponds to the 1-mile buffer. It will be highlighted on the map itself.

On the Main Menu, click Tools, then Geoprocessing Wizard.

Chose Clip one layer based on another, then Next>.

Select the input layer to clip: cities_dtl

Select a polygon clip layer: The Bond_Buf15 file (or Bond_Buf15_trunc file). MAKE SURE that the Use selected features only box has a checkmark in it.

Specify the output shapefile: cities1_clip in the installation directory.

Then click the Finish button**.**

The new cities1_clip file will appear on the TOC. Right click on cities1_clip, click on Open Attribute Table and read the number of rows. This is the value of Towns within 1 mile. Right click on the column POP_98. Click on the Statistics option. The Statistics of cities1_clip box will appear. Enter the value of SUM: as the Town Population within 1 mile. Note: There must be at least 1 individual per town even if the POP_98 says less. This prevents division by zero.

Town density & ratios. The Excel sheet formulas divide the number of towns by the 1992 Count for each 1- to 5- and 0- to 1-mle buffers. They then divide the 0- to 1-mile density by the 1- to 5-mile density. A ratio greater than 1 means the towns are more numerous near the installation boundary, an undesirable situation.

Population density & ratios. The Excel sheet formulas divide the Population by the 1992 Count for each 1- to 5- and 0- to 1-mile buffers. They then divide the 0- to 1-mile density by the 1- to 5-mile density. A ratio great than 1 means the Population is greater near the installation boundary, an undesirable situation.

Step 6.5 Save Table to Trend directory.

To make a final report to TABS office, save one copy of the table to the installation directory and another to the Trend directory. The Trend directory is located at the same level on the hard disks as the InstallationName directories. It is from this location you will generate the report.

Step 7: Quality Control and Wrap up

Step 7 General description: Although you may have gone through the procedure, you need to ensure that each product represents the situation correctly. To answer these questions objectively, fill out a form for each installation and save it as a MS Word .doc in the installation folder. Finally there is a procedure to save the InstallationName directory to DVDs for backup locally and for submission to the TABS Office.

Step 7.1 Complete Quality Evaluation

Although you may have gone through the procedure, you need to ensure that each product represents the situation correctly. Since the NLCD is a USGS/EPA (Environmental Protection Agency) product, you can assume it is correct. That leaves the question of the quality of the Ikonos classification and the resulting table. Since the table is a simple summary of the NLCD and Ikonos classification, if you get the Ikonos classification right, the table will present the results correctly. Therefore, issues of quality control uniquely revolve around the Ikonos classification. The following are the criteria by which the urban classification will be judged:

1. Does inspection show a good match between the Ikonos classification and what makes sense based on the Ikonos image?
2. Does inspection show that areas that are not urban are excluded based on the Ikonos image?
3. How much urban is excluded from the urban category?
4. How much non-urban is captured within the urban category?
5. What are the thresholds of acceptable?
6. Is there an acceptable percent for incorrect (non-urban included and urban excluded)?

To answer these questions in a more objective manner, revise the answers you made in Step 4.6 in the Preliminary Quality Evaluation and save your answers as a MS Word .doc in the installation folder. If there are any changes, make sure that those changes are reflected in the urbbuf_92-01 excel files.

Step 7.2 Wrap-Up

This is a good time to clean up the intermediate files. For each file you no longer need, right click on the name in the TOC and choose Remove. There should be only 4 layers left in the final .mxd document for the installation.
These are: installationName_boundary, urbbuf_92_01g, Buf15_G, and ikonos_study_area.img, descending in that order. Double click on the Buf15_G layer to open the Layer Properties dialog box. Click on the Display tab and set the transparency of the layer to 80%. Close the Layer Properties dialog box by clicking

the OK button. In ArcCatalog right click on the name of the intermediate files and choose Delete.

You have to save the data you have generated. With the directory structure suggested, it should be feasible to save the entire installation data to a couple DVDs. The concept is that all data used will be within the installation directory. In addition the .mxd ArcMap file will be there too. For anyone else to read the data and the .mxd file, all they would have to do is copy the entire installation directory to their local machine and open the .mxd.

To make the .mxd file portable:

Open ArcMap .mxd file from the installation directory.
Click on File, Map Properties click on Data Source Options.
Make sure the Store Relative Path Names, box is checked. If it is not, do so. Click OK, OK.
Save the .mxd.

Make two copies of the entire installation directory. Once you are sure the copies are readable, you can erase the installation directory from the hard disk. One copy will be sent to the IVT office, the other kept as backup.

3 Discussion of General Land Use Change Indicators

This project was designed to determine the land use change near military installations. There are many metrics to measure this change. This chapter discusses the characteristics of all the metrics and what they indicate. To satisfy the requirements of this project, this discussion does not name individual installations, nor are data or comments presented that would allow identification of individual installations. If the reader requires knowledge about individual installations, contact the TABS Office directly.*

First, let us deal with what is believed to be the primary measure of urbanization, then later with secondary measures. Percent of area near an installation that was urbanized was not adequate as the ultimate measure because it did not tell about the rate of change, which was developed by comparing the 1992 NLCD to the 2003 Ikonos images. On the other hand, the rate of change by itself could be misleading because a large rate could be caused by the addition of a few houses, for example in a desert, which overall would not make much difference. Further, since the installations are of vastly different sizes, researchers needed a way of comparing them fairly. For example, it is possible that a 200% increase in urbanization near an installation in the middle of a desert could represent one house being joined by two new houses. However, dividing by the percent increase by the area (i.e., number of unit areas used — or "cells") you normalize the increase for the size of the installation (e.g., correct for situations where a large percentage increase represents an insignificant change). The actual resulting numbers look strange (3.02E-7) because the process divides a percent (usually in the range of 2% to 4%) by a huge number. All installation buffers contain a large number of cells. The standard size used was 12.5 meters on edge/cell. In a square kilometer there would be 80,000 cells. Even the 1-mile buffers were almost always many square kilometers. The factor is called the *Urbanization Rate/Developable Cell*. It is a measure of urbanization because it takes into account both the rate of growth and size.

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* Headquarters, Department of the Army, DASA-IA, (ATTN: William Tarantino, ASA-IA), 1400 Key Boulevard, Nash Building, Suite 200, Arlington VA 22209 or by telephone at 703-696-9529.

The team calculated the *Urbanization Rate/Developable Cell* in a series of steps that were integrated into the MS Excel® spreadsheet. The value is determined as follows:

UrbanizationRate/Developable Cell
= Increase%/Year (Developable)/
Count_of_#_cells_that_are_Developable_in_that_Buffer

Increase%/Year (Developable)
=Increase Urban % (Developable)/number of years between 1992 and image date

Increase Urban % (Developable)
=% Urban in image - % urban in 1992
{this is how we integrate the date difference}

where:
Count_of_#_cells_that_are_Developable_in_the_Buffer
is read from one of the tables supporting that buffer

There are a few more preliminary steps preceding the above equations where we:

Corrected for those cells that cannot be developed (e.g., lakes).

Corrected for what we believed were systematic errors that the imagery analysis had introduced but which could be numerically characterized.

Corrected for cell sizes that vary between steps.

In fact there were two *Urbanization Rate/Developable Cell* values. One is the simple classical Straight-Line Trend analysis method; the other is called the Monomolecular Trend analysis method. While the straight-line projections could (and did) go over 100% near some installations, the more sophisticated monomolecular projection (an exponentially based geometric curve tending to a 100% asymptote) ensures that the rate will taper off so growth will never exceed 100%. In any area, the best land for development is usually used first. Poorer parcels are developed later. As the parcel suitability decreases, the development rate slows. This trend is the common sense situation that the monomolecular equation represents. At no installation did the monomolecular projection go over 99% developed, while the straight-line projection did. In the straight-line method, the rate is the slope of the line between the percent urbanized in 1992 and 2003. However, the monomolecular graph shows a curve — the rate of change varies continuously. The curve is fit to the origin; the 1992 value, and the 2003 value such that it tends to 100%. In the monomolecular method, the “rate” is the slope of the tangent to the curve at any point. For our projection equation, we used the “instantaneous” or “maximum” rate that is the slope of the tangent at the origin.

How different were the two techniques? For the TABS office we ranked all the installations (97 total) based on the *Urbanization Rate/Developable Cell* index by both techniques. In comparing the straight-line vs. monomolecular rankings, no difference or little difference (+1 or -1) was found in the ranking in 63% of the installations. A difference of 9 positions in the ranking occurred once (in the middle of the rankings). Otherwise, all rankings were within a difference of 6. Thus, it was concluded that the rankings are stable and largely independent of the trend method used.

What are the characteristics of encroachment as represented in this set of military installations? The following statements are findings from the data presented in Table 2. The following statements reflect the 0- to 1-mile buffer data (with the 1- to 5-mile buffer data in parentheses).

- The current percent-developed urban land (high and low density residential plus commercial and transportation land per the categories defined in the USGS NLCD) near military installations is 26% (24%) with a standard deviation of 26% (24%). This indicates that, in general, about a quarter of land is developed, but that a good deal of variation exists in the encroachment character among installations. One installation is 88% (93%) surrounded.
- The straight-line increase per year is on the average 1% (1%) but can be as much as 3% (4%) while the mean monomolecular yearly growth rate is 2% (2%) but can be up to a maximum of 13% (13%). The monomolecular "instantaneous" growth rate tends to be higher in earlier stages of encroachment; so by this indicator, most installations are still in the "youthful" stages of encroachment.
- The Straight-Line Trend to 2020 results in a predicted average 35% (38%) urban encroachment and as great as 144% (157%). The monomolecular predictions for 2020 are less at 30% (28%) with as much as 99% (98%) encroachment possible. Significantly, the predictions by these two methods are at odds. Straight-line trend suggests that the areas in the 1- to 5-mile buffer away from the installation will develop faster than those directly adjacent to the installation (i.e., the 0- to 1-mile buffer). The monomolecular predicts that areas adjacent to the installations will develop faster.

Table 2. Evaluation statistics for buffer zones.

Summary Statistic	Current Urban %	Straight Line Increase%/Year	Straight-Line Trend to 2020 %Urban	Monomolecular maximum yearly growth rate	Monomolecular Trend to 2020 % Urban	Current Urban %	Straight Line Increase%/Year	Straight-Line Trend to 2020 %Urban	Monomolecular maximum yearly growth rate	Monomolecular Trend to 2020 % Urban
	0-1 Mile Buffer	0-1 Mile Buffer	0-1 Mile Buffer	0-1 Mile Buffer	0-1 Mile Buffer	1-5 Miles Buffer	1-5 Miles Buffer	1-5 Miles Buffer	1-5 Miles Buffer	1-5 Miles Buffer
Mean	26%	1%	42%	2%	37%	23%	1%	38%	1%	33%
Standard Deviation	26%	1%	35%	2%	30%	24%	1%	34%	2%	28%
Maximum	88%	3%	144%	13%	99%	93%	4%	157%	13%	98%

4 Statistical Evaluation

This chapter contains a statistical summary of encroachment indices for each of several variables for the Army installations (population of 89) and a comparison of these values to those of the other Services (population of 8 installations). It also includes a comparison of the statistic for the buffer zone from 0- to 1-mile to the 1- to 5-mile buffer zone. The purpose was to draw out anything significant about the characteristics of urbanization and how that varies within the immediate installation environment and the broader region (as characterized in the 1- to 5-mile buffer).

Methods

Table 3 contains a list of the variables used in the analyses. Of these variables, the one labeled "RelativeGrowthRate," or RGR, was not included in the set of variables listed in the Protocol. This variable was calculated for each buffer of each installation as:

$$RGR = \{\log_e P_2 - \log_e P_1\}/\{Year_2 - Year_1\}$$

Where P stands for the proportion of developable pixels classed as "urban," the subscripts 1 and 2 refer to the time order of the observations, with Year1 = 1992 and Year2 = 2001, with some variation in this year among installations.

Statistical calculations were performed using SAS®/BASE and SAS®/STAT software of SAS® Release 8.02, under Microsoft Windows® 5.0.2195. The analyses of covariance were calculated using a mixed-models approach, employing SAS® PROC MIXED using a protocol for statistical model selection essentially similar to that described in Littell et al. (1996, pp. 176, 201-211). The model was run separately for each independent variable listed in Table 3, and tested the effects of the class variables "Buffer" and "Military Department," using the log10 transform of the Installation Area as a covariate. Where significant "covariate × class variable" interactions were found, these effects were taken to represent the data better than using a single covariate slope, and the results were interpreted accordingly. The class variable "Installation" was included in the model as a random effect nested within each military department. Statistical significance always refers to significance at the traditional $\alpha = .05$ level.

Table 3. Variables used in statistical analyses, their interpretations, and the data transformation performed.

Dependent Variable Name	Interpretation	Transformation
General		
Log10Area	Installation Area (sq. m)	log10
Log10Perimeter	Installation Perimeter (m)	log10
PrelimQuality	Preliminary quality assessment of imagery analyses (values 0-5)	None
QualityEval	Final quality evaluation of imagery analyses, expressed as approximate percent that the number of pixels classed as “Urban” was overestimated in the final imagery analysis.	None
Anaylses of Covariance (using Log10Area as covariate)		
Class Variables:		
Installation	Name of installation	
MilDept	Military department (Army vs. Other) to which the installation belongs	
Buffer	Buffer zone surrounding the installation (1 = 0- to 1-mile buffer, 2 = 1- to 5-mile buffer)	
Dependent Variables (for each buffer on each installation):		
PctUndevel	Percentage of pixels in 1992 considered undevelopable (unsuitable for eventual development into urban pixels)	arcsin(square-root)
TownsWithin	Count of towns within buffer in 1992	square-root
DensTownPop	Density of town population (population per unit buffer pixel area) in 1992	sixth-root
Ratio_LDH_HDH	Ratio of Low-Density-Housing to High-Density-Housing pixels in 1992	log10
Pct92_CommTransp	Percentage of Commercial transportation pixels in 1992	arcsin(square-root)
DensRoadsWithin	Density of roads per unit pixel area in 1992	square-root
CorrPctUrbDev_Start	Percentage of developable pixels classed as urban in 1992 (corrected for over- or underestimation of urban pixel counts).	arcsin(square-root)
StraightLineSlp	Rate of increase in the percentage of total developable urban pixels per year (Linear Model)	square-root
RelativeGrowthRate	Growth rate of urban pixels per urban pixel (Exponential Model) (urban pixels per urban pixel per year, = year^{-1})	log10
MonoMaxGrowthRate	Maximum growth rate of the percentage of developable pixels classed as urban per year (Monomolecular Model)	square-root
MonoPctUrb2020	Projected percentage of developable pixels classed as urban in 2020 (Monomolecular Model)	arcsin(square-root)
LinearPctUrb2020	Projected percentage of developable pixels classed as urban in 2020 (Linear Model)	square-root
URDC	Urbanization rate per developable cell per year (Linear Model)	Log10(x) + 10

Results

Installation Area and its relation to Installation Perimeter. *Length of installation perimeter.* The greater the length of the edge of an installation, the greater the potential for incompatible land uses along this perimeter.

The distribution of installation areas (in square meters) is shown in Figure 6. The mean ± standard deviation of $\log_{10}$-transfomed areas was 7.682 ± 1.137, having an acceptably normal distribution (Shapiro-Wilk W = 0.981518, p = .23), with this average corresponding to about 48 square km, and with area values ranging from 0.073 to 20319 square km.

The $\log_{10}$-transfomed installation perimeters were related to $\log_{10}$-transfomed areas by a regression equation with a slope (± standard error) of 0.51984 ± 0.01194 and an intercept of 0.60320 ± 0.09153. The regression line is plotted in Figure 7. The slope of this line is somewhat higher than the value of 0.5 that might be expected from the typical Euclidian relationship of perimeter to area, but not significantly so, with Pr (0.49607 < slope < 0.54362) = 95%. As Figure 7 shows, the perimeter-area relationship is not statistically different from what might be expected for circles or squares of comparable area. **This means that in general, the outlines of the installations do not lend themselves to encouraging encroachment.**

The residual data values of the perimeter-area regression relationship can be interpreted as an index of the relative length of the perimeter for a given installation area. Table 4 shows that these residuals were positively, but rather weakly, correlated with the three indices of encroachment used in this study.

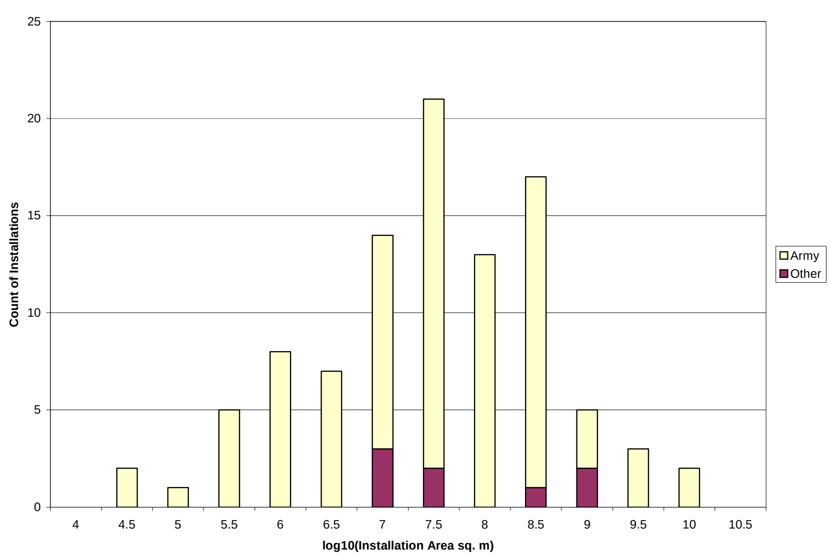

Figure 6. The distribution of values for log10(Installation Area), with stacked frequencies for levels of Military Department = "Army" vs. "Other Departments."
Log10(Installation Area) values are truncated to the lowest multiple of 0.5.

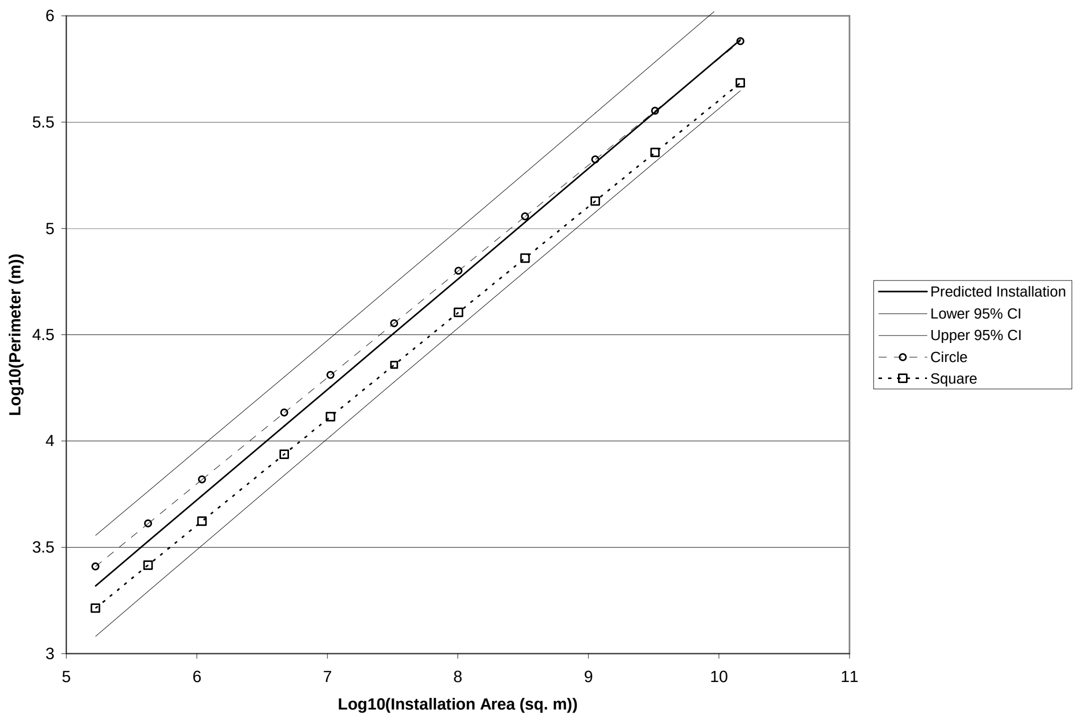

Figure 7. The scaling relationship of installation perimeter to installation area, as calculated by regression using log10-transfomed values.

The heavier solid line represents the regression line (see text for parameter values), while the lighter solid lines represent upper and lower 95% confidence bands for the line. The dashed lines depict the hypothetical perimeter values calculated for circles and squares of comparable area.

Table 4. Correlations of the values of residuals from the regression relationship of installation perimeter vs. installation area with the values of variables that served as indices of urban "encroachment."

Variable		Transform	Sample Size	Pearson's r	p-value	Kendall's tau-b	p-value
CorrPctUrbDev_Start	Buffer 1	arcsin(square-root)	81	0.2218	0.0466	0.2142	0.0046
CorrPctUrbDev_Start	Buffer 2	arcsin(square-root)	80	0.2159	0.0545	0.1747	0.0218
MonoPctUrb2020	Buffer 1	arcsin(square-root)	81	0.2433	0.0286	0.1617	0.0326
MonoPctUrb2020	Buffer 2	arcsin(square-root)	80	0.2359	0.0351	0.1601	0.0355
LinearPctUrb2020	Buffer 1	square-root	81	0.2623	0.0180	0.1667	0.0276
LinearPctUrb2020	Buffer 2	square-root	80	0.2506	0.0249	0.1646	0.0307

Quality estimations

In addition to conducting statistical analysis, the analysts were asked to describe their individual sense of the quality of the results. A preliminary quality evaluation was done for each installation. For each installation, a number between 0 and 5 (with 5 being the best) was assigned based on the analyst's feeling of how well the

outcome reflected the actual situation. The most common assignment was 4. Forty installations were given a rating of 4, 15 were given a rating of 5, 24 were given a rating of 3. Only 11 installations were given a rating of 2 or 1.

The distribution of subjective preliminary quality evaluations for the data from each installation (with 0 being the worst and 5 being the best) is shown in Figure 8. The majority of the installations were deemed to have reasonably satisfactory data, with a mode at quality level 4, and the great majority with quality levels of 3 to 5.

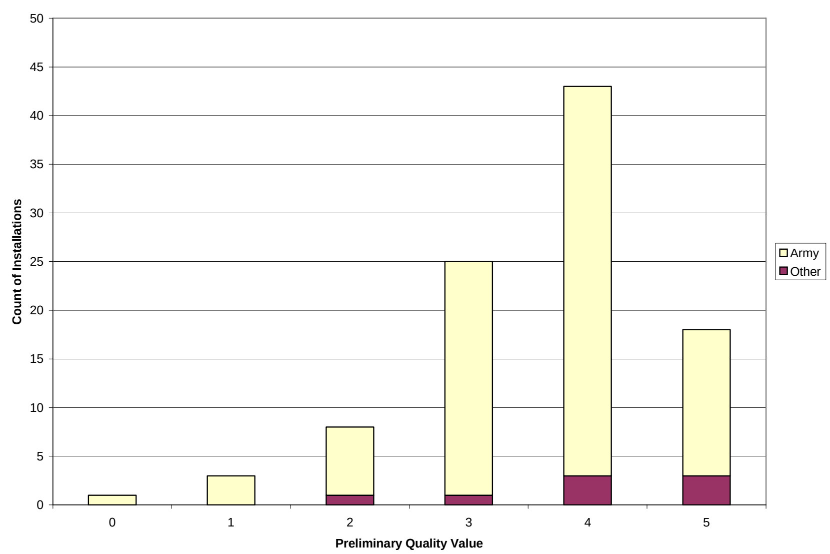

Figure 8. The distribution of values for the preliminary quality assessment, with stacked frequencies for levels of Military Department = "Army" vs. "Other Departments."
0 represents the worst quality, while 5 represents the best.

In addition to assigning the preliminary quality rating, each analyst looked at their information and assigned two percentage values. The first was the percentage of land area that the analyst thought overestimated — urbanization that did not exist, (e.g., 10 percent). In addition, the analysts assigned another percentage for urbanization indicated in the analysis, but was known not to occur. The difference between these two numbers became the "over/under" estimate. The over/under estimate was used to correct the final percentage as reported to the TABS office. Looking at the statistics for all of these numbers indicates that the analysts judged that the process tended to overestimate more often than underestimate.

The distribution of the final quality evaluation, representing the percentage by which number of urban pixels was assessed to be overestimated (in the subjective appraisal of the analyst) is shown in Figure 9. The distribution had a mean ± standard deviation of 4.45% ± 10.63%, significantly different than 0 (1-sample $t = 4.14$, $N = 98$, $p < .0001$), showing a small but significant tendency for overestimation of the number of urban pixels. **This suggests that our Protocol tended to overesti-**

mate urbanization but in a consistent fashion across installations, therefore it does not impact comparative analysis.

Neither the preliminary nor the final quality evaluations showed any correlation with log10(Installation Area) at the .05, or even the .1, level of significance, for either parametric (Pearson's r) or non-parametric (Kendall's tau-b) correlations. **So there was no relationship between the installation size and its quality evaluation.**

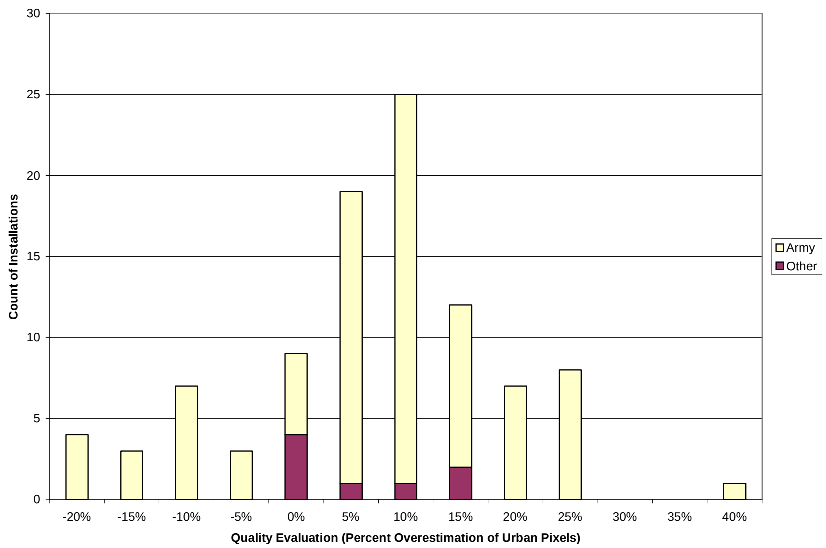

Figure 9. The distribution of values for the final quality assessment, with stacked frequencies for levels of Military Department = "Army" vs. "Other" Departments.

The quality assessment value represents the percentage by which number of urban pixels was subjectively assessed, by the analyst, to be overestimated in the final grid file product, with negative values indicating underestimation.

Analyses of covariance for 12 dependent variables

Variables Reflecting Conditions in 1992. The issue here is what is the mix of land use types that can cause encroachment? It would be difficult and unreliable to pull this information from the Ikonos images, but it can be read directly from a newly created layer.

Count of Undevelopable land 1992. If land is undevelopable, it will help protect the installation against encroachment. Although there are many considerations that would contribute to undevelopable land, in this study is limited to Open Water, Perennial Ice/Snow, Bare Rock/Sand/Clay and Quarries/Strip Mines/Gravel Pits as defined in the NLCD (see Step 5.6). The evaluation is conducted for the different buffers to see how well protected the installation is. There is a value for the 0- to 1-mile buffer and another for the 1- to 5-mile buffer. The ratio of these two values, sug-

gests how well the nearby areas are naturally protected from development. Ratios greater than 1 suggest that the installation is more protected.

Analysis of Covariance (ANCOVA) results pertaining to the percent of land that deemed unsuitable for urban development (PctUndevel) are shown in Table 5, row (a). No significant effects due to either military department or buffer were found.

Table 5. Final models used in analyses of covariance, and results expressed as p-values.
Cells containing "---" indicate that the effect was dropped from the final model for lack of significance. Some effect significance values greater than, but close to, the α = .05 level are shown. "ns" represents not statistically significant at the 0.05 level. The two random effect columns contain variance component estimates, not p-values. The variables labeled (a)-(g) represent conditions in 1992. The variables labeled (h)-(j) represent growth rates, and the variables labeled (k)-(l) represent projected urbanization by the year 2020. See Table 3 for variable definitions.

		Class Effects p-values			Covariate Effects p-values				Random Effect Variance Components	
ID	Dependent Variable	MilDept	Buffer	MilDept × Buffer	Log10(Area)	Log10(Area) × MilDept	Log10(Area) × Buffer	Log10(Area) × Buffer × MilDept	Installation Nested Within MilDept	Residual
(a)	PctUndevel	ns	ns	ns	---	---	---	---	0.05438	0.006624
(b)	TownsWithin	ns	0.0025	ns	---	---	---	---	0.2853	0.8189
(c)	DensTownPop	ns	ns	ns	0.0033	---	---	---	0	0.1090
(d)	Ratio_LDH_HDH	ns	ns	ns	---	---	---	---	0.01353	0.002669
(e)	Pct92_CommTransp	ns	<.0001	ns	<.0001	---	<.0001	---	0.009867	0.003535
(f)	DensRoadsWithin	ns	ns	ns	<.0001	---	---	---	1.78E-06	2.25E-06
(g)	CorrPctUrbDev_Start	ns	0.0004	ns	<.0001	ns	0.0015	---	0.0487	0.0061
(h)	StraightLineSlp	ns	ns	0.0345	ns	ns	ns	0.0368	0.0016	0.000256
(i)	RelativeGrowthRate	ns	0.0132	ns	<.0001	---	0.0117	---	0.1468	0.02684
(j)	MonoMaxGrowthRate	ns	ns	ns	<.0001	---	---	---	0.003505	0.000463
(k)	MonoPctUrb2020	ns	.0636	ns	<.0001	---	---	---	0.08366	0.01151
(l)	LinearPctUrb2020	ns	0.0321	0.0683	0.0662	ns	0.0496	0.0755	0.05960	0.008368
(m)	URDC	ns	< .0001	0.0606	<.0001	---	---	---	0.5508	0.1821

Towns within 5 miles and Town Population within 5 miles. The more towns that exist near the installation, the more attractiveness there exists for potential development to occur. Note: There must be at least 1 individual per town even if the POP_98 says less. This prevents division by zero. This data generates the Town density and ratios. A ratio greater than 1 means the towns and populations are greater near the installation boundary, an undesirable situation. Of the Army installations in this study, the mean of this index was 3.8 (1.8 for Other Services). Since the ratio is greater than 1, this is the less desirable situation where the population is greater near the installation boundary.

Analysis of Covariance (ANCOVA) results pertaining to the number of towns present (TownsWithin) are shown in Table 5, row (b). There was a significant difference between buffers, illustrated in Figure 10. The 1- to 5-mile buffer tended to

have more towns that the 0- to1-mile buffer. **This means that the installation boundary is not an attractor to establishment of towns.**

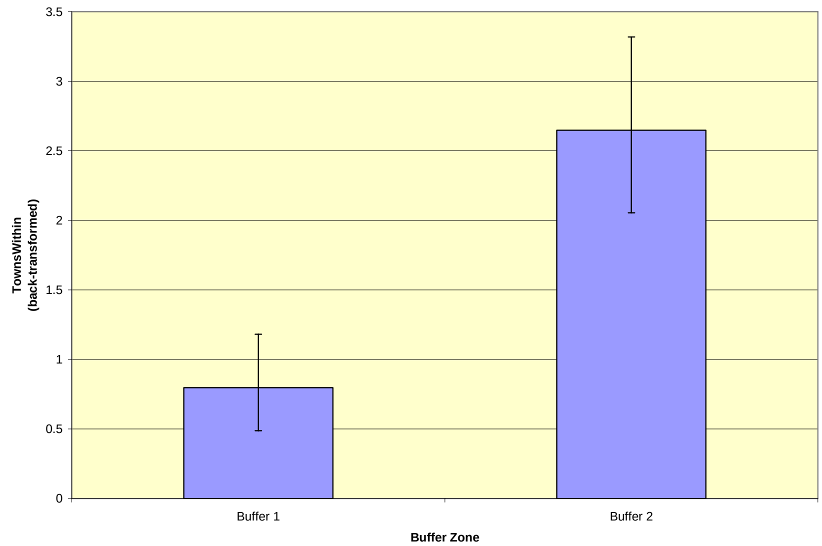

Figure 10. Least-squares means for the count of towns within each buffer (TownsWithin), from the analysis of variance presented in Table 5, row (b).
Error bars represent 1 standard error (back-transformed). Buffer 1 = 0 to1 mile. Buffer 2 = 1 to 5 miles.

Town Population within 5 miles. The greater the population near the installation, the more attractiveness there exists for potential development to occur. Of the Army installations in this study, the mean of the town population index was 3.8 (1.8 for Other Services). Since the ratio is greater than 1, this is the more desirable situation where the population is greater away from the installation boundary. The variation in the standard deviations (Army 13.5, Other Services 2.1) is great enough that crossing over the 1.0 threshold would be easily accomplished.

Analysis of Covariance (ANCOVA) results pertaining to the density of the urban population per unit pixel of buffer (DensTownPop) are shown in Table 5, row (c) and Table 6, row (c). The only significant effect was the installation area covariate, with no significant effects of military department or buffer zone. These results are illustrated in Figure 11, with a line representing the relationship of urban population density with installation area. **This means as installation area increases, adjacent population density decreases quasi-exponentially.**

Table 6. Regression parameter estimates from the analyses of covariance presented in Table 5.

The labels in the ID column correspond to the analyses with the same ID labels in Table 5. Where a 2-factor or 3-factor "Covariate x Class Variable" effect was significant, the regression parameters were estimated separately for each level of that class variable combination.

					Regression Relationship to Log10Area			
ID	Dependent Variable	Transformation	MilDept	Buffer	Intercept	Standard Error	Slope	Standard Error
(a)	PctUndevel	arcsin(square-root)			---	---	---	---
(b)	TownsWithin	square-root			---	---	---	---
(c)	DensTownPop	sixth-root			0.9079	0.1844	-0.0684	0.0229
(d)	Ratio_LDH_HDH	loq10			---	---	---	---
(e)	Pct92_CommTransp	arcsin(square-root)		1	0.9544	0.0863	-0.0984	0.0111
				2	0.6656	0.0865	-0.0643	0.0112
(f)	DensRoadsWithin	square-root			0.0145	0.0013	-0.0012	0.0002
(g)	CorrPctUrbDev_Start	arcsin(square-root)		1	1.6291	0.1621	-0.1687	0.0209
				2	1.3500	0.1621	-0.1368	0.0209
(h)	StraightLineSlp	square-root	Army	1	0.1531	0.0307	-0.0088	0.0040
			Army	2	0.1731	0.0307	-0.01177	0.0040
			Other	1	0.2425	0.1388	-0.01954	0.0172
			Other	2	0.1021	0.1388	-0.00284	0.0172
(i)	RelativeGrowthRate	log10		1	-2.9957	0.2910	0.2431	0.0375
				2	-2.5654	0.2912	0.1893	0.0375
(j)	MonoMaxGrowthrate	square-root			0.2797	0.0444	-0.0231	0.0055
(k)	MonoPctUrb2020	arcsin(square-root)		1	1.8864	0.2067	-0.1636	0.0266
				2	1.8421	0.2067	-0.1636	0.0266
(l)	LinearPctUrb2020	square-root	Army	1	1.6155	0.1856	-0.1349	0.0240
			Army	2	1.5448	0.1857	-0.1298	0.0240
			Other	1	1.3935	0.8401	-0.1102	0.1041
			Other	2	0.5352	0.8401	-0.0098	0.1041
(m)	URDC	log10(x)+10	Army	1	5.5297	0.5572	-0.4720	0.0719
			Army	2	4.8218	0.5571	same	same
			Other	1	5.3816	0.6510	same	same
			Other	2	5.0967	0.6510	same	same

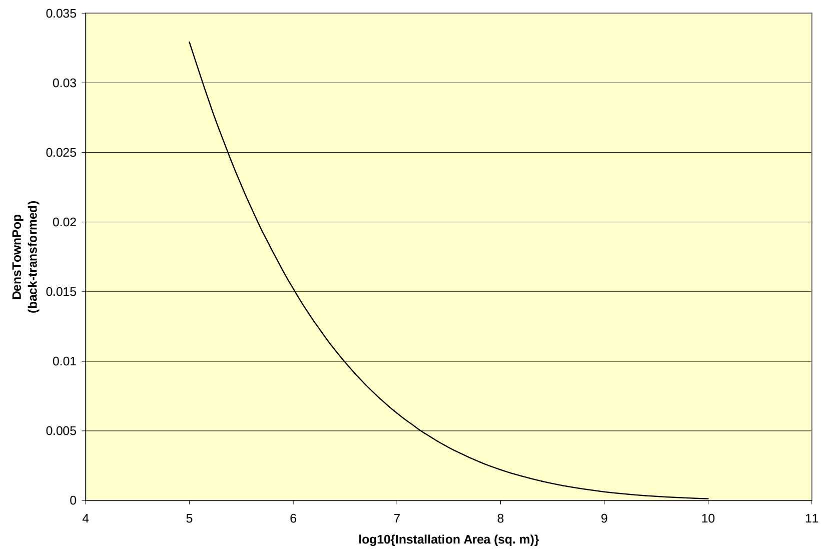

Figure 11. The relationship of town population density (DensTownPop) to installation area, from the analysis of covariance presented in Table 5, row (c).

The 1- and 5-mile 1992 Count of Low Density Housing and the 1- and 5-mile 1992 Count of High Density Housing are read directly from the data. The ratio, the 1- and 5-mile 1992 Low to High Density Ratio, is used to characterize the growth demographics between the Low Density Housing and High Density Housing. The Ratio of Low to High density compared between the 1- and 5-mile buffers shows the character of the development near the installation. A ratio greater than 1 shows more low-density housing near the installation. The greater the value, the more predominant the low-density housing is near the installation. Of the Army installations in this study, the mean of the Low to High-density housing index was 4.0 (0.8 for Other Services). Since the ratio is greater than 1, this is the more desirable situation where the low-density housing is greater near the installation boundary than further away. Interestingly, the situation is reversed for the Other Services. There is enough variation in the standard deviations (Army 16.2, Other Services 0.5) that in both, crossing over the 1.0 threshold would be easily accomplished.

Analysis of Covariance (ANCOVA) results pertaining to the ratio of low-density housing pixels to high-density housing pixels (Ratio_LDH_HDH) are shown in Table 5, row (d). No significant effects were found for military department, buffer zone, or installation area.

The 1- and 5-mile 1992 count of Commercial Transportation. This category represents more intense land use. The question is, “Does the installation tend to attract higher intensity types of land use?”

Analysis of Covariance (ANCOVA) results pertaining to the percentage of commercial transportation pixels (Pct92_CommTransp) are shown in Table 5, row (e) and

Table 6, row (e). The significant interaction effect "Log10(Area) × Buffer" implies that the relationship of this dependent variable to installation area is different for the different buffer zones. This effect is illustrated in Figure 12. **So the answer to the question "Does the installation tend to attract higher intensity use types of land use?" is Yes for relatively small installations, and No for the large installations based on a comparison of the two buffers.**

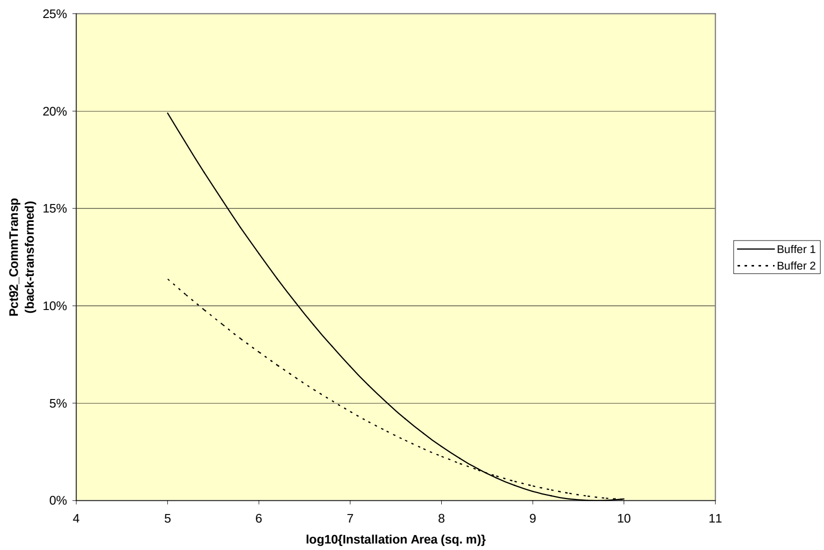

Figure 12. The relationship of the percentage of commercial transportation pixels (Pct92_CommTransp) to installation area, separately for each buffer, from the analysis of covariance presented in Table 5, row (e).

For details of variable descriptions, see Table 3. Buffer 1 = 0 to 1 mile. Buffer 2 = 1 to 5 miles.

Length of Roads Within 5 miles. The presence of roads is a very important attractor for development. In fact, development rarely occurs unless road access already exists. Although it is conceded that roads of different types will show different degrees of attraction for development, this research considerd roads to all be of the same type, as developed and defined in Step 2.5 of the Protocol. The ratio of Roads/unitarea within 1 mile divided by Roads/unitarea within 5 miles generates an index. A number less than 1 is good – it means that the intensity of road building near the installation is less than is characteristic of the nearby regions.

Of the Army installations in this study, the mean of the Roads per unit area index was 1.9 (1.0 for Other Services). Since the ratio is greater than 1, this is the less desirable situation where the road density is greater near the installation boundary than further away. Interestingly, the index is exactly 1.0 for the Other Services; for them, there is no difference. There is enough variation in the standard deviations (Army 6.8, Other Services 0.4) that crossing over the 1.0 threshold would be easily accomplished.

Analysis of Covariance (ANCOVA) results pertaining to the length of roads within each buffer per unit pixel of buffer (DensRoadsWithin) are shown in Table 5, row (f) and Table 6, row (f). The only significant effect was the installation area covariate, with no significant effects of military department or buffer zone. These results are illustrated in Figure 8, with a line representing the relationship of road density with installation area. **The result is that there seems to be no difference in roadage adjacent to versus near the installation.**

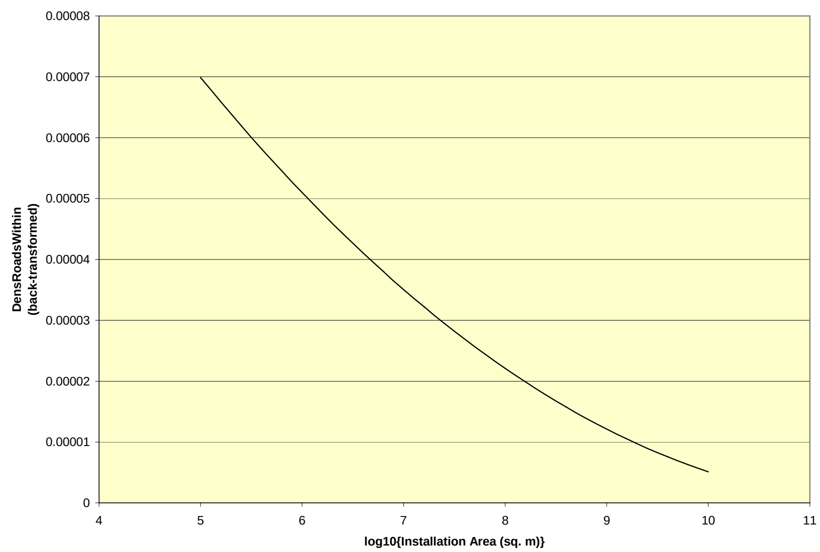

Figure 13. The relationship of road density (DensRoadsWithin) to installation area, from the analysis of covariance presented in Table 5, row (f).

Percentage Of Developable Pixels Classed As Urban. The greater this number, the more urban-developed is the area around an installation.

Analysis of Covariance (ANCOVA) results pertaining to the (corrected) percentage of developable pixels classed as urban in 1992 (CorrPctUrbDev_Start) are shown in Table 5, row (g) and Table 6, row (g). The significant interaction effect "Log10(Area) × Buffer" implies that the relationship of this dependent variable to installation area is different for the different buffer zones. This effect is illustrated in Figure 14. **This means that for small installations, areas closer to the installation boundaries tend to be more developed than areas further away, but as the installations increased in size, the difference became negligible.**

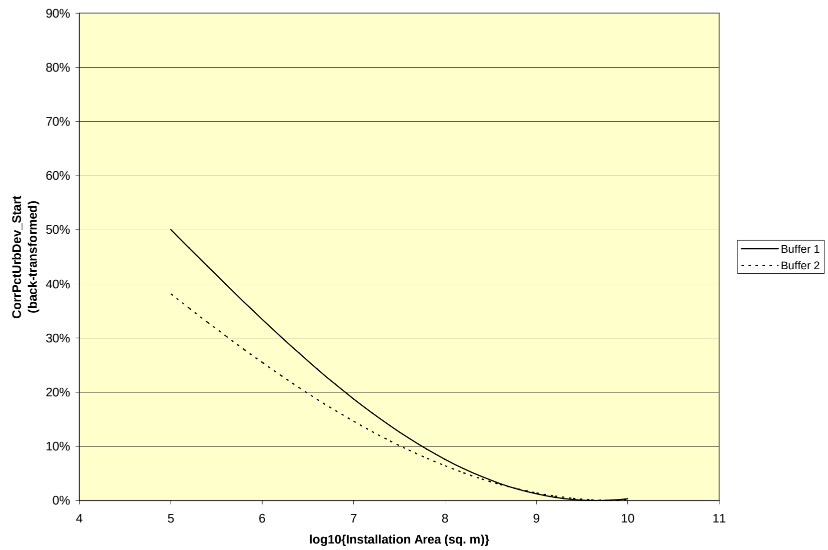

Figure 14. The relationship of the percentage of developable pixels classed as urban in 1992 (CorrPctUrbDev_Start) to installation area, separately for each buffer, from the analysis of covariance presented in Table 5, row (g).

For details of variable descriptions, see Table 3. Buffer 1 = 0 to 1 mile. Buffer 2 = 1 to 5 miles.

Variables reflecting urban growth between 1992 and 2003

Classical Straight-Line Trend Analysis Method is simply a line drawn on a graph between % urban in 1992 and the date of the Ikonos imagery (usually in the year 2003). The research team extended the graph to the year 2020 to find what percentage value that line would indicate in 2020. The slope of the line is the yearly rate of growth.

Analysis of Covariance (ANCOVA) results pertaining to the linear rate of increase in the percentage of total developable urban pixels per year (StraightLineSlp) are shown in Table 5, row (h) and Table 6, row (h). The significant interaction effect "Log10(Area) × MilDept × Buffer" implies that the relationship of this dependent variable to installation area was different for the different combinations of military department and buffer zone. This effect is illustrated in Figure 15. Figure 15 shows that:

1. As the size of an installation grows, the straight-line growth rate goes down.

2. The straight-line growth rate for Army installations is indistinguishable between buffers. For installations other than Army (a small sample), the growth rate situation is not clear enough to make a conclusion.

3. The straight-line growth rate varies between Military Services. The Army's growth tends to be more similar between the buffers compared to the other Services.*

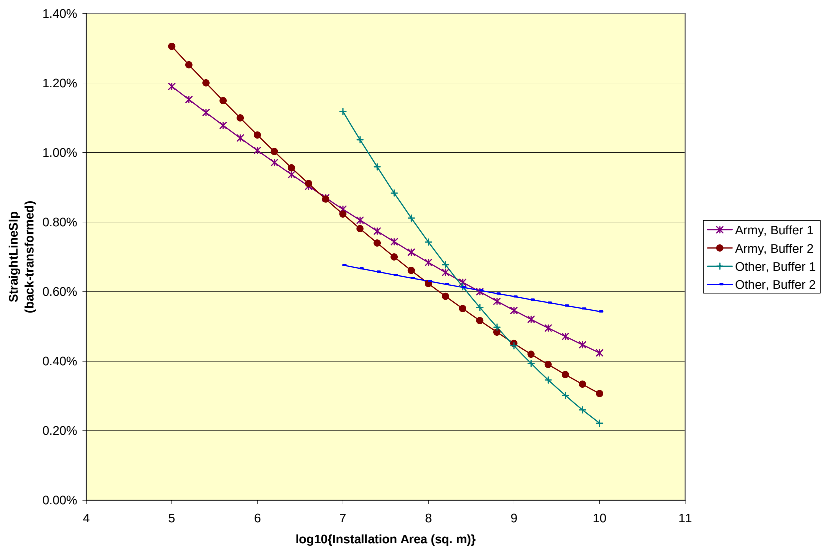

Figure 15. The relationship of the linear rate of increase in the percentage of total developable urban pixels per year (StraightLineSlp) to installation area, from the analysis of covariance presented in Table 5, row (h).

The relationships are drawn separately for each combination of military department and buffer. For details of variable descriptions, see Table 3. Buffer 1 = 0 to 1 mile. Buffer 2 = 1 to 5 miles.

The "RelativeGrowthRate," or RGR, (not included in the set of variables listed in the protocols) was calculated for each buffer of each installation as explained in the Methods section (page 64).

Analysis of Covariance (ANCOVA) results pertaining to the annual growth rate of urban pixels per urban pixel assuming an exponential growth model (RelativeGrowthRate), are shown in Table 5, row (i) and Table 6, row (i). The significant interaction effect "Log10(Area) × Buffer" implies that the relationship of this dependent variable to installation area is different for the different buffer zones. This effect is illustrated in Figure 16. **It means that the relative growth rate is less for areas adjacent to the installations than for areas more distant at smaller installations but the trend reverses for the larger installations.**

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* Keep in mind that the sample is not random and that the sample of 89 Army locations is much larger than the other Services (8). Though it is likely that the large number of Army installations probably is representative, the same cannot be said for the Other Services.

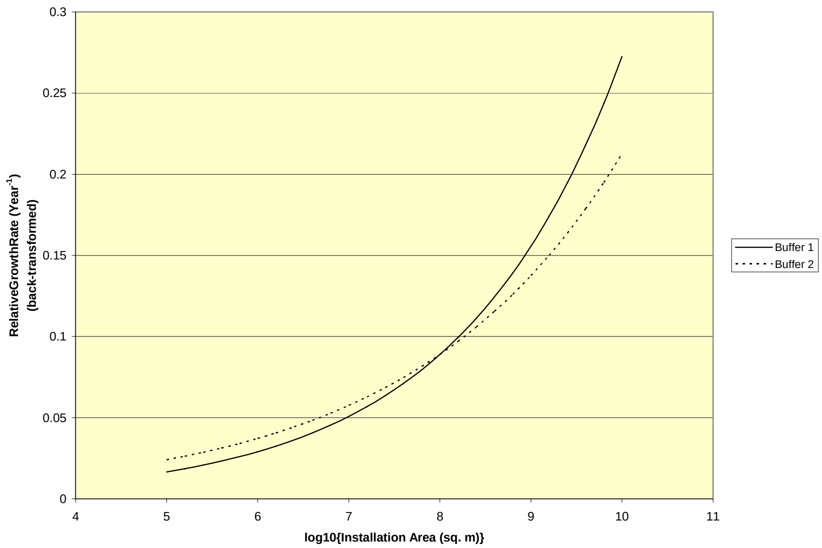

Figure 16. The relationship of the annual growth rate of urban pixels per urban pixel assuming an exponential growth model (RelativeGrowthRate) to installation area, separately for each buffer, from the analysis of covariance presented in Table 5, row (i).
For details of variable descriptions, see Table 3. Buffer 1 = 0 to 1 mile. Buffer 2 = 1 to 5 miles.

UrbanizationRate/Cell/buffer. A normalized value for the rates in the buffers across-installations was calculated as %Increase/Year divided by the BufferCount. There was a value for the 0- to 1-mile buffer and another for the 1- to 5-mile buffer.

1mile vs. 5mile buffer Increase/Year ratio. A ratio greater than 1 indicates urbanization occurred at a greater rate near the installation – this is less desirable than a value less than 1, which indicates urbanization is occurring at a lower rate near the installation.

Analysis of Covariance (ANCOVA) results pertaining to the urbanization rate per developable cell per year (URDC) are shown in Table 5, row (m) and Table 6, row (m). The covariate effect "Log10(Area)" was highly significant. There was also a strongly significant effect of buffer, and a marginally non-significant "MilDept × Buffer" interaction. This implies that the slopes of the relationship of URDC to area were essentially the same, with the significant differences due to MilDept and Buffer relating to differences in the y-intercepts for these relationships. This effect is illustrated in Figure 17. For Army installations, statistical comparison of least-squares means showed that the line depicting URDC for Buffer 1 was significantly higher than that for Buffer 2 ($p < .0001$). None of the other lines differed significantly from one another at the .05 level. Figure 17 shows that, of the installations in this study, the **rate of growth in the adjacent buffer was higher than the further distant areas. Otherwise there was little difference to be found among other factors.**

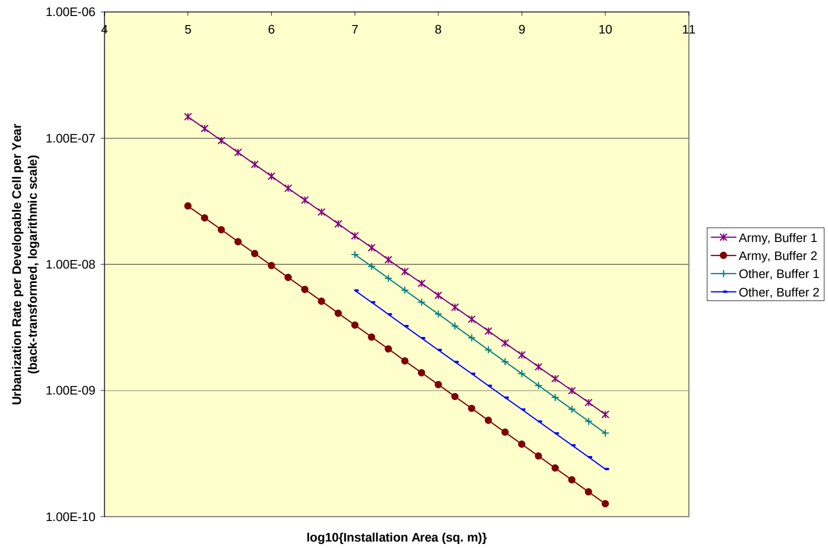

Figure 17. The relationship of the urbanization rate per developable cell per year (URDC) to installation area, from the analysis of covariance presented in Table 5, row (m).

The relationships are drawn separately for each combination of military department and buffer. Values on the vertical axis are presented on a logarithmic scale. For details of variable descriptions, see Table 3. Buffer 1 = 0 to 1 mile. Buffer 2 = 1 to 5 miles.

The **monomolecular projection** is a concave, non-linear growth curve, beginning at zero, fitted to the two year points (1992 and 2003 % urban) and tending to a 100% asymptote. It ensures that the rate will taper off so growth will never exceed 100%. In any area, the best land for development is usually used first. Poorer parcels are developed later. As the parcel suitability decreases, the development rate slows. This trend is the common sense situation that the monomolecular equation represents. The MonoMaxGrowthRate growth rate is that growth rate that would exist if there were almost no urbanization already. Since as development occurs, the value of the growth rate decreases, the MonoMaxGrowthRate is also near the initial growth rate value.

Analysis of Covariance (ANCOVA) results pertaining to the maximum growth rate of the percentage of developable pixels classed as urban per year, based on the monomolecular growth model (MonoMaxGrowthRate) are shown in Table 5, row (j) and Table 6, row (j). The only significant effect was the installation area covariate, with no significant effects of military department or buffer zone. These results are illustrated in Figure 18, with a line representing the relationship of maximum growth rate with installation area. **This data shows that when using the monomolecular equation, the growth rate can be expected to decrease with larger installations in a quasi-exponential fashion.**

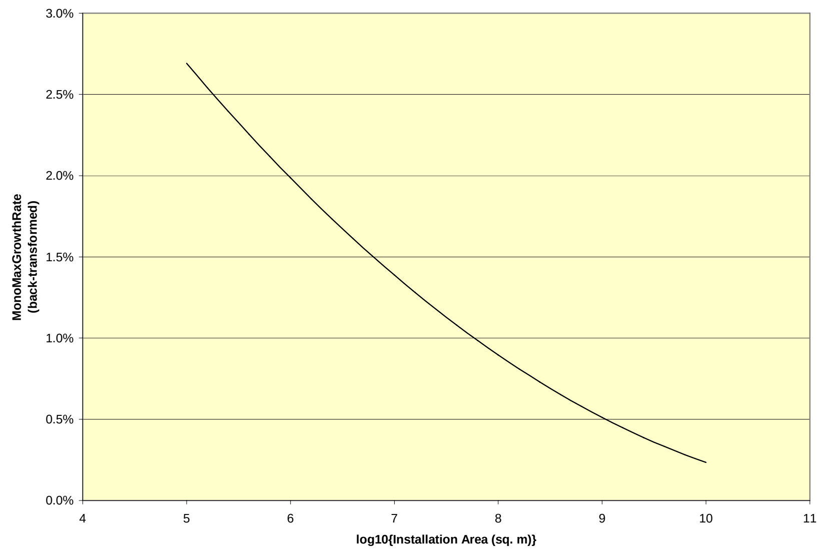

Figure 18. The relationship of the maximum growth rate of the percentage of developable pixels classed as urban per year, based on the monomolecular growth model (MonoMaxGrowthRate) to installation area, from the analysis of covariance presented in Table 5, row (j).
For details of variable descriptions, see Table 3.

Variables reflecting encroachment of urban lands by 2020

For the **monomolecular projection** pertaining to the projected proportion of developable pixels classed as urban in 2020 (MonoPctUrb2020), the results are shown in Table 5, row (k) and Table 6, row (k). The only significant effect was that the installation area was covariate, meaning that as the size of the installation increased, the monomolecular projection would tend to decrease. There was no significant effect relating to military department. However, the effect of buffer zone was very close to significant at the .05 level, suggesting that the functional relationships of MonoPctUrb2020 with installation area were slightly different, but parallel lines on a log scale. **The interpretation of this finding is that as the installation area increased, the monomolecular prediction decreased in a similar proportion for each buffer, but the nearer areas would have a slightly greater percentage of urbanization than the further areas.** These results are illustrated in Figure 19.

Analysis of Covariance (ANCOVA) results pertaining to the projected proportion of developable pixels classed as urban in 2020 using the Linear Model (LinearPctUrb2020) are shown in Table 5, row (l) and Table 6, row (l). The significant interaction effect “Log10(Area) × MilDept × Buffer” implies that the relationship of this dependent variable to installation area was different for the different combinations of military department and buffer zone. This effect is illustrated in Figure 20.

Figure 20 can be read to mean that as the area of an installation increased:

- There would be decrease in urbanization in all Army areas and in Other Services adjacent areas.
- As a whole, the Army installations were similar to Other Services installations except for less adjacent areas that, for other Services, didn't vary much with installation area.

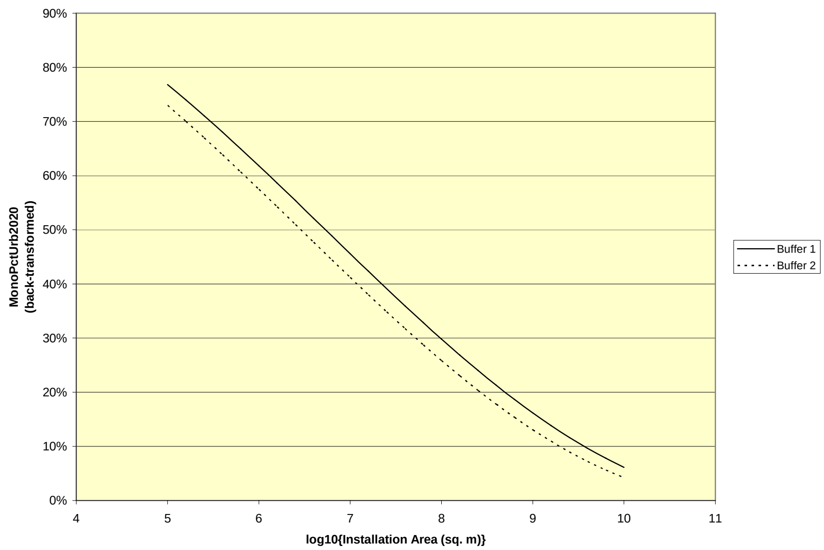

Figure 19. The relationship of the projected proportion of developable pixels classed as urban in 2020 using the Monomolecular Model (MonoPctUrb2020) to installation area, separately for each buffer, from the analysis of covariance presented in Table 5, row (k).

For details of variable descriptions, see Table 3. Buffer 1 = 0 to 1 mile. Buffer 2 = 1 to 5 miles.

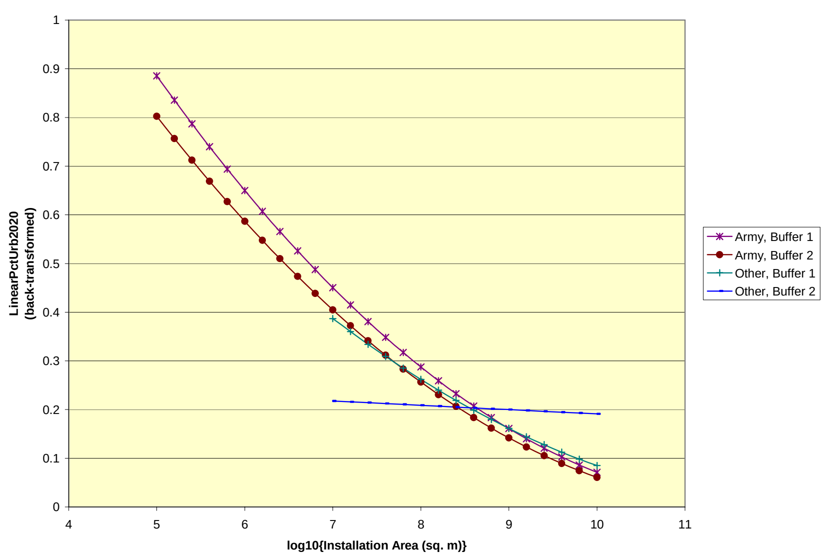

Figure 20. The relationship of the projected proportion of developable pixels classed as urban in 2020 using the Linear Model (LinearPctUrb2020) to installation area, from the analysis of covariance presented in Table 5, row (l).

The relationships are drawn separately for each combination of military department and buffer. For details of variable descriptions, see Table 3. Buffer 1 = 0 to 1 mile. Buffer 2 = 1 to 5 miles.

Discussion of Statistical Issues

Scale

The first, and most striking, feature of the data was the range of installation areas represented in the data set; a range that spanned nearly 6 orders of magnitude. Because the issue of scale was thus an important consideration in the interpretation of the data, all variables analyzed were tested in some way for their potential relationships to installation area. This proved to be worthwhile, since some variables had complex functional relationships to installation area, such that omission of area from the analyses would have produced misleading results.

The relationship of installation perimeter to installation area was about what would be expected; perimeter scaling as approximately the square root of the area. **The positive correlation of the residuals of the perimeter-area regression with three measures of urban encroachment suggests that installations with large perimeters for their area (i.e., more convoluted perimeters) tended to be more vulnerable to encroachment.** The effect, however, was rather weak.

Quality assessment

There is little to interpret regarding the preliminary quality and final quality assessments, beyond the results presented. Preliminary quality was substantially skewed to the left, indicating a relatively high subjective assessment of quality overall. The final quality assessment showed a statistically significant average tendency for the subjective assessment of the number of pixels classed as urban to be an overestimate of what the assessor thought to be the actual value.

Aspects of urban encroachment in 1992

The analyses in Table 5, rows (a) through (g) dealt with variables relating to urbanization around installations in 1992. Some results were of relatively minor import. The percentage of land considered by the assessor to be undevelopable as urban land did not differ with respect to buffer zone, military department, or installation area, and so was not a confounding factor in any of the subsequent analyses. The ratio of low-density housing to high-density housing also showed no statistically significant relationships among these factors.

The number of towns within each buffer was higher overall for the 1- to 5-mile buffer than for the 0- to 1-mile buffer (Figure 10), which was not surprising, given that the former buffer tended to encompass more surrounding area than the latter. The density of the urban population within each buffer (Figure 11), and the density of roads within each buffer (Figure 13), declined dramatically as installation area

increased. This is perhaps unsurprising, since larger installations tend to be located in unpopulated regions, predominantly in the western portion of the United States, whereas the eastern United States contains a larger number of small installations in relatively populous locations. Neither of these variables, however, showed significant differences due to military department or buffer zone.

The percentage of commercial transportation pixels (Figure 12), and the percentage of developable pixels classed as urban in 1992 (Figure 14) exhibited significantly different relationships to installation area for the 0- to 1-mile buffer vs. the 1- to 5-mile buffer. For smaller installations, the 0- to 1-mile buffer showed significantly higher values for these variables than the 1- to 5-mile buffer, suggesting higher levels of urbanization and commercialization in the region closest to the installation boundary. However, this difference between the buffers decreased to essentially nothing for larger installations, and the overall averages decreased concomitantly to very low levels relative to the smaller installations.

Thus, in 1992, urbanization was higher overall for smaller installations compared to larger installations, and, at least for commercial transportation and percent of pixels classed as urban, urbanization was higher near the installations than further away, but this difference was not apparent for larger installations.

Growth in the percentage of land classed as urban, 1992-2001

The analysis of covariance results for the simplest estimate of urban growth, the linear (absolute) increase in percentage of urban pixels per year, showed a weakly significant ($p = .036$) 3-factor interaction among the military department and buffer zone class variables, and installation area covariate. This yielded complex results that were difficult to interpret (Figure 15). The general trend was for this absolute growth rate to decrease with increasing installation area, which is perhaps unsurprising since, as mentioned previously, larger installations tend to be built in unpopulated regions. It is unclear why these relationships would differ among combinations of military department and buffer zone.

The results for the relative growth rate (Figure 16), or growth rate of urban pixels per urban pixel per year, were also complex, but somewhat less difficult to interpret. The RGR in the 0- to 1-mile buffer was lower than the RGR in the 1- to 5-mile buffer for small installations, but this difference became 0 for installations near 10^8 square meters (i.e., 199 sq km), and reversed itself above this value. Comparison with the results shown in Figure 14 provides a possible interpretation for this pattern. In 1992, on smaller installations, urbanization was higher in the buffer near the installation than in the buffer farther from it. This could imply that, for small installations, the land closer to the installation was closer to its “carrying capacity” for urbanization than land further away. In that case, the potential for further growth

would have been higher in the buffer zone further from the installation. On the other hand, with increasing installation size, the difference in urbanization between the near and far buffers declines dramatically, allowing the trend to be reversed for large installations. The results for very large installations may be somewhat inflated, since they were based on very low counts, and percentages, of urban pixels per buffer.

The maximum growth rate, as calculated using the "monomolecular" urban growth model, declined with increasing installation area, but showed no statistically significant effects due to military department or buffer zone. Under the monomolecular model, this variable indicates what the absolute growth rate of the percentage of urban pixels "would be" when the percentage of urban pixels is far below its "carrying capacity" of 100%.

The urbanization rate per developable cell (URDC) declined exponentially with increasing installation area. For Army installations, this rate was higher in the buffer closest to the installation boundary. For non-Army installations, the difference between buffers was not clear, but the pattern of decline with increased installation area was consistent with that seen for the Army installations.

Urban encroachment projected for year 2020

The monomolecular model, in theory, provides a more reasonable estimate for the projected percentage of pixels classed as urban in 2020, since under this model the projected percentage cannot exceed 100%. The results using this model showed that the percentage of urban pixels would be expected to be quite high for smaller installations, but much lower for large installations, with only a small, non-significant difference between the 0- to 1-mile buffer and the 1- to 5-mile buffer at all installation sizes. This result is most usefully interpreted by contrast with the comparable percentages of urban pixels in1992 (Figure 21), which probably represents the most informative result of the present study. The comparison of these figures suggests that, if the growth trends measured in this study continue:

- Urbanization of the land surrounding the installations will increase substantially for all installations,
- Urbanization will remain higher for small than for large installations, and
- For smaller installations, the urbanization of the 1- to 5-mile buffer will "catch up" to the levels of urbanization on the 0- to 1-mile buffer, resulting in a more homogeneously high level of urbanization throughout the entire 0- to 5-mile buffer range examined in this study.

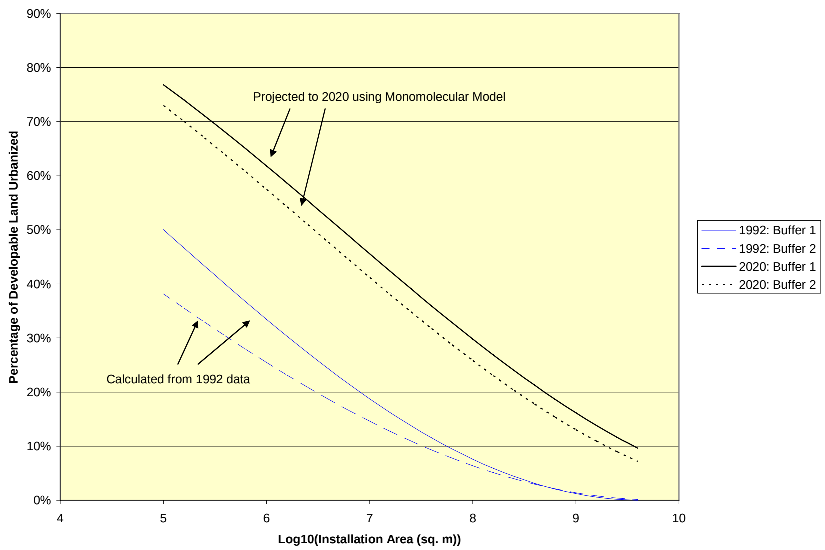

Figure 21. The percentage of developable land urbanized in 1992 vs. the projected values for 2020 under the monomolecular model.

This figure is comprised of Figures 14 and 19 superimposed. Buffer 1 = 0 to 1 mile. Buffer 2 = 1 to 5 miles.

The projected levels of percentage of urban pixels using the linear growth model were calculated for comparison (Figure 20). As with the case for the linear growth rate (Figure 15), the linear prediction is difficult to interpret, due to the effect of a somewhat mysterious 3-factor interaction among military department, buffer zone, and installation area. For all cases except the combination of Buffer = “1-5 mile buffer” and Military Department = “Other,” the predicted values are similar to the predictions using the monomolecular model, if perhaps somewhat higher than the latter for small installations. This may simply be due to the fact that predicted values of the linear model are not constrained to be less than or equal to 1. Both the monomolecular and straight-line techniques will result in similar conclusions. So for purposes of encroachment prediction, it does not matter which technique is used – the resulting story will be largely the same. This is particularly true for Army installations.

5 Summary and Recommendations

Summary

Many DoD installations are experiencing increased pressure on aspects of their military mission activities due to urban development of land uses near the installation boundaries. To understand and anticipate this phenomenon, it is useful to establish the historical urban growth trend in areas surrounding an installation. Recent advances in computer analysis techniques based on remotely sensed satellite imagery have allowed the establishment of a scientifically derived baseline for development growth near an installation.

In this task, ERDC evaluated 97 military installations in terms of urban land use change and the characteristics of that encroachment on the installations. This report describes in detail the Protocol by which this was accomplished. Analyses were completed for each installation using a 1- and 5-mile buffer. Land use changes were determined by comparing the National Land Cover Data – NLCD (dated roughly 1992) to Ikonos satellite images (taken in 2001 to 2003). These data for each installation were reported to the TABS office for integration into their multi-consideration evaluation program.

This compilation of data is the largest large data set of detailed, compatible information on the status of encroachment near military installations. To take advantage of this unique set of data, a series of statistical evaluations of both the procedure and results were carried out. This evaluation is here used to characterize the encroachment status of military installations as represented by the installations in the sample.

The results of the analyses provide a unique snap shot on the status of urban encroachment at military installations for the Army (and might suggest the status for the other Services). The following paragraphs represent a summary of the significant characteristics of urbanization near military installations.

- With a good deal of variation, about a quarter of the land is developed near military installations. One installation is 88% surrounded. Several are 0% surrounded by urban land uses.
- The straight-line increase per year is on the average 1% while another technique, the monomolecular, results in a 2% rate. The monomolecular "instantaneous" growth rate suggests that many installations are still in the "youth-

ful" stages of encroachment (e.g. rated land use change in the installation perimeter is increasing).

- The maximum "monomolecular" growth rate declines with increasing installation area.
- The urbanization trend predictions for the year 2020 suggest an average encroachment in the range of 30% to 35%.
- Installations with convoluted perimeters adjoining privately owned lands tended to be more vulnerable to encroachment.
- The density of the urban population within each buffer and the density of roads within each buffer declined dramatically as installation area increased, but this is in part because larger installations tend to be located in unpopulated regions, predominantly in the western portion of the United States, adjoining public lands.
- If these growth trends continue, urbanization of the land surrounding the installations will increase substantially for most installations,
- Both the straight-line and monomolecular projection methods result in similar conclusions. For predicting encroachment, the method does not matter – the resulting story will be the same. The two approaches are sufficient for comparative analysis across installations; exactness of the estimate would require additional work.

The following statements paint a concise picture of the urbanization around military installations. Although there is a great deal of variation, about 25% of the nearby land is urbanized and by 2020 this will increase by about a third (to about 33%). Any differences in urbanization rates between areas adjacent to installations (0- to 1-mile buffer) and areas further away (1- to 5-mile buffer) will disappear by 2020. These predictions are largely independent of the method used to make them.

Recommendations

Based on the goal of finding ways to prevent urbanization from potentially impacting the military mission of installations, the following recommendations are made:

- Additional lands are needed, in some cases, to "buffer" installation activities from incompatible land uses.
- A comprehensive study is needed to examine the relative risk of change to perimeter lands and the relative risk to mission, to identify priority locationns for land agreements and land acquisition actions across the Army and perhaps across all service installations and ranges.

This report avoids naming individual installations for reasons of confidentiality. As a result of this study, the data exists to generate another more detailed evaluation

of urbanization character and risks. It is recommended that this investigation be funded and carried out.

It is also recommended that when similar urbanization studies are carried out, the Protocol developed and documented for this tasking be adopted so that the results will be comparable to those generated in this study. By this means, a larger database will be made available on which to carry out other studies. Because of the limitations within Ikonos imagery, we recommend using alternative imagery sources (Landsat, SPOT, or ASTER) for future research, which could provide additional insights. However, the availability of the Ikonos imagery for a large number of Defense installations in a common time frame (2001-2004) may outweigh the disadvantages of the imagery.

Appendix A: Protocol for Installations Without NLCD Data

For some installations, USGS NLCD data did not exist. For these, a different evaluation was carried out in order to generate the data needed for the TABS office.

Approach

The analysis of urban area growth using other than NLCD data uses U.S. Bureau of Census, Census 2000 Urban Areas shape files. These files were obtained from the U.S. Bureau of Census Web Site (Figure A1).

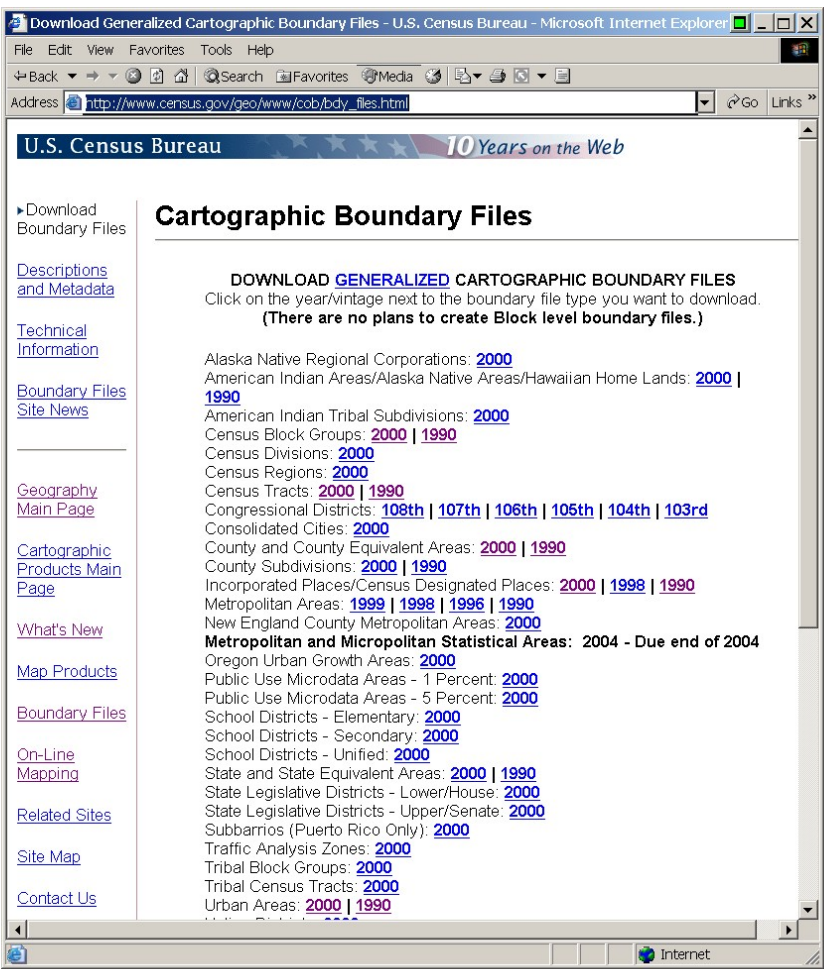

Figure A-1: U.S. Bureau of Census Web Site.

Once downloaded the files are re-projected to WGS84, which is the projection environment of the standard TABS Protocol. A study area shape file and 1- and 5-mile buffer file were created using the Ikonos Imagery (provided by the IVT Office, era 2001 to 2003) and the installation boundary file. To accomplish this, the procedure in Step 2 of the TABS Encroachment Protocol was followed. Next, an edit of the 2000 Census Urbanized Area shape file was conducted. Using the Ikonos imagery and a GIS roads layer (time period 2001) provided in the standard Protocol, the boundaries of the urbanized area shape file were corrected to reflect the full extent of urban development. This newly edited urban area shape file becomes the basis for the extent of urban development in 2001. To provide a basis for the extent of urban development in 1992, a similar editing process was applied using a roads file that is as close to the 1992 time period as possible. The source of this earlier road layer information is the municipal GIS web sites, the United States Geological Survey, and NGA.

The two urban area maps created by this process serve as the source of information for change in urban area form 1992 to 2001. This information when entered into the TABS Protocol Trends Spreadsheet yields the percentage of yearly growth, the percentage of area developed, the straight-line 2020 growth expectation and monomolecular 2020 growth expectation. Additional information regarding length of installation perimeter, roads per unit area, and the number of cities within the 1- and 5-mile buffer can be acquired by completing the appropriate sections of Step 6.4 of the standard TABS Protocol.

Source Material Used in the Analysis of these Installations included:

- 2000 Urbanized Areas Map, Department of Commerce, Census Bureau, Geography Division, January 1, 2000. An urbanized area (UA) consists of densely settled territory that contains 50,000 or more people. A UA may contain both place and nonplace territory. The U.S. Census Bureau delineates UAs to provide a better separation of urban and rural territory, population, and housing in the vicinity of large places. At least 35,000 people in a UA must live in an area that is not part of a military reservation.
- Military Installation Map 1:50,000, Defense Mapping Agency Hydrographic/-Topographic Center, Washington D.C. 1986.
- Ikonos Imagery provided by the Office of the Assistant Chief of Staff for Installation Management (OACSIM).
- Road Map per regular TABS Encroachment Protocol.
- U.S. Geological Survey (USGS) 1:25,000-scale Digital Line Graphs; ROADS, 1992.
- Municipality Parcel Maps. Data layer containing platted, surveyed, and deeded parcel lines, right-of-way lines, as well as attribute information.

Appendix B: Getting Additional Data from the IVT office

If the study area or 5-mile buffer requires more Ikonos imagery coverage, immediately make a request for it. After requesting the imagery, you will be able to download it via ftp.

Contact IVT POC:
Office of the Assistant Chief Of Staff
for Installation Management (OACSIM)
Plans and Operations (DAIM-MD)

Download from FTP site:
You'll be notified when the data is available at the FTP site.
ftp://gis.hqda.pentagon.mil
This may require downloading several images.

Once you are at ftp://gis.hqda.pentagon.mil/Lozar/, select (highlight) the files you wish to Download, right click on the selected files. On the pop-up menu box, choose Copy to a folder, and when the Browse for Folder window appears, navigate to (or make a new folder) for the IkonosImagery. Click OK. Download time runs about 20 minutes per installation. It will be slowest during mid-day.

Uncompress the files. You will have to use WinZip to decompress the files. Double click on the file name. The .zip extension should cause WinZip to appear (if not, see your system administrator). Click I agree to the license agreement page, then on the menu click the Extract button. The Extract to: window will appear. Navagate to the Ikonos directory and then click the Extract button. Make sure your disk has enough room (extracted tiles are about 0.5 G each. Repeat for each tile sent to make up the installation.

Appendix C: Alternatives for Step 2: Define Rectangular Study Area and Bond_buf15_trunc.shp

In some cases the initial study area will extend beyond the imagery available. You need to modify the study area to reflect only the area for which imagery data is available. To do this, follow this procedure:

- On the ArcMap Toolbar, choose the “Identify” button.
- Click on the map at the locations where the study area box needs to be modified. Record the X, Y Location: values.
- In ArcMap, click on the Edit toolbar and choose Start Editing
- Choose the directory to edit in which the StudyArea file resides.
- On the Editor toolbar, the Target is the StudyArea.shp file, the Task is to Modify Feature
- Make sure the Edit Tool arrow is selected, move it over one of the edge lines (not in the interior) and right click. Select Properties to bring up the Edit Sketch Properties window.
- In the Edit Sketch Properties window you change the values of the X,Y corner points to make them reflect the truncated coordinates you wrote down.
- Click Finish Sketch and dismiss the Edit Sketch Properties window.
- On the Editor toolbar, click the Editor down arrow, then Stop Editing, then answer Yes to Do you want to save your edits?

For the same reason, you may also have to modify the buffer created to reflect the lack of complete Ikonos coverage. After you have done the above, follow this procedure for the buffer:

- On the Main Menu, click Tools, then Geoprocessing Wizard.
- Chose Clip one layer based on another, then Next>.
  - Select the input layer to clip: Bond_Buf15
  - Select a polygon clip layer: The truncated StudyArea
  - Specify the output shapefile: Bond_Buf15_trunc
- Then click the Finish button.

The new Bond_Buf15_trunc file will appear on the TOC.

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Acronyms and Abbreviations

Term	Spellout
AOI	Area of Interest
ArcGIS	GIS Software package from ESRI
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CERL	Construction Engineering Research Laboratory
CRREL	Cold Regions Research and Experiment Laboratory
DoD or DOD	Department of Defense
DVD	Digital video disk
EPA	U.S. Environmental Protection Agency
ERDAS	A company that makes software for Remote Sensing
ERDC	U.S. Army Engineer Research and Development Center
ESRI	A Company that makes GIS software
FTP	File Transfer Protocol
FGDC	United States Federal Geographic Data Committee. The FGDC has the lead role in defining spatial metadata standards.
GDT	Company Name
GIS	Geographic Information Systems
GRID	A format for saving GIS data in a cell form rather than line form
GRS	Grid Reference System
Ikonos	Name of a remote sensing satellite instrument
IMAGINE	An ERDAS software package
IVT	Installation Visualization Technology (office)
LANDSAT	Name of a remote sensing satellite
MS	MicroSoft®
NAD	North American Datum
NIMA	National Imagery and Mapping Agency
NGA	National Geospatial-Intelligence Agency (formerly NIMA)
NIR	Near Infrared (one of the bands of satellite imagery)
NLCD	National Land Cover Data
POC	Point of Contact
RGR	Relative Growth Rate
SAS	A company that makes statistical software
TABS	Total Army Basing Study (office)
TIFF	Tagged Image File Format, a graphic file format developed by Aldus and Microsoft.
TM	Thematic Mapper
TOC	Table of Contents
USGS	U.S. Geological Survey
WGS	World Grid System

REPORT DOCUMENTATION PAGE

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14. ABSTRACT

The Total Army Basing Study (TABS) office, as one aspect of their stationing study, wished to determine the rate of development near the boundaries of nearly 100 military installations throughout the United States. The Engineer Research and Development Center proposed that this could be done by comparing the urbanization as derived from Ikonos images (taken around 2003 and acquired for all Services through the National Geospatial-Intelligence Agency) to a digital land use data set developed by the United States Geological Survey in about 1992. This decade difference could then be used to determine not only the amount of development, but also the trend. For the military, increasing development near installation boundaries can limit the ability to carry out their primary responsibilities of military training readiness and material testing activities. A team of 10 professionals was able to carry out the analysis for all the installations in about 4 months. This document describes the standard procedure used and the generalized results for the trends in increased development near the installation boundaries. It also summaries the urbanization trends from the statistics generated to provide a snapshot of encroachment characteristics near a sample of nearly 100 military installations.

15. SUBJECT TERMS

encroachment	Total Army Basing Study (TABS)	urbanization
land use planning	IKONOS	

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